SECOND EDITION

INTERACTION OF MAN & THE BIOSPHERE

INQUIRY IN LIFE SCIENCE

IMB

INTERACTION SCIENCE CURRICULUM PROJECT

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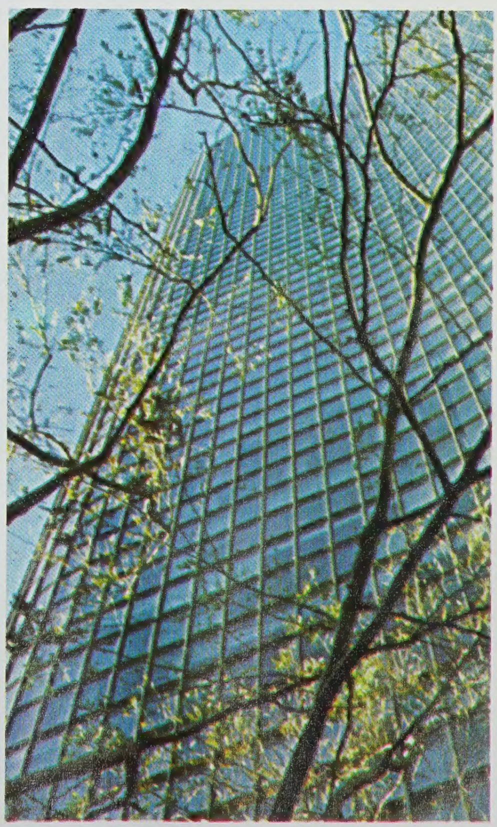

NORMAN ABRAHAM

RICHARD G. BEIDLEMAN

JOHN A. MOORE

MICHAEL MOORES

WILLIAM J. UTLEY

RAND McNALLY & COMPANY

Chicago • New York • San Francisco • London

Printed in U.S.A.

IMB

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Contributors

Authors

NORMAN ABRAHAM Director: Interaction Science Curriculum Project. Science Curriculum Consultant, Yuba City (California) Unitied School District, 1966–1970. Coauthor, *Interaction of Matter & Energy* (Rand McNally, 1973) and *Interaction of Earth & Time* (Rand McNally, 1972). Associate Director, Biological Sciences Curriculum Study, 1964–1966. Served as Supervisor of the BSCS Second Course.

RICHARD G. BEIDLEMAN Professor and Chairman, Biology Department, Colorado College, Colorado Springs. Member, BSCS Green Version Writing Team, 1966–1968. Served on the BSCS Steering Committee. Active in the AIBS Visiting Biologist Program.

JOHN A. MOORE Professor of Biology, Department of Life Sciences, University of California at Riverside. Member, National Academy of Sciences. Supervisor, BSCS Yellow Version Writing Team, 1960–. Served on the BSCS Executive and Steering committees. Member, AAAS Commission on Science Education.

MICHAEL MOORES Biology Teacher, Yuba City (California) High School. Coauthor, *Interaction of Earth & Time* (Rand McNally, 1972). Instructor, Teacher Orientation Program, Interaction Science Curriculum Project.

WILLIAM J. UTLEY Chairman, Science Department, Yuba City (California) High School. Member, BSCS Second Course Writing Team, 1962–. Consultant to Adaptation Team, BSCS Blue Version for Japanese Schools, Tokyo, 1965–1967. Instructor, Teacher Orientation Program, Interaction Science Curriculum Project.

Writing Associates

David Hummel Science Teacher, Yuba City (California) High School.

Thomas Rodgers Professor Emeritus of Biology, Chico State College, Chico, California.

Consultants for the First Edition

Michael Bakis Science Teacher Grades 7–8, Gray Avenue Intermediate School, Yuba City, California

Lois Barber Science Teacher Baltimore City Schools, Maryland

Donald Chaney Science Teacher Los Gatos High School, California

Curtis Clowdus Science Teacher Grades 7–8, Weaverville Elementary School, California

Ingrith Deyrup Olsen
Department of Zoology, University of Washington, Seattle

Paul Pearson Department of Zoology Rutgers College, New Brunswick, New Jersey

Gerald Scherba Vice-president for Academic Affairs, California State College at San Bernardino, California

Robert Stegner Associate Professor Departments of Biology and Education University of Delaware, Newark

Consultants for the Second Edition

Stephen Almansi
Chairman, Science Department
Northport Junior High School
Northport, New York

Darwin Blue Science Teacher
Jefferson County Schools
Golden, Colorado

Curtis S. Clowdus Science Teacher
Weaverville Elementary School
Weaverville, California

Herbert L. Harris
Chairman, Science Department
Klinger Junior High School
Southampton, Pennsylvania

Hugh Kinsey Meteorologist
Horace Mann Space Center
Dayton Public Schools
Dayton, Ohio

James P. Knerl Science Department
Francisco Junior High School
San Francisco Unified School District
San Francisco, California

Lona Lewis Science Teacher
Parkway Schools
Creve Coeur, Missouri

William G. Miller Science Department
East Northport Junior High School
East Northport, New York

Jean A. Richmond Science Teacher
Burnet Junior High School
Austin, Texas

Jean G. Smith Science Coordinator
Orland School District #135
Orland Park, Illinois

Robert W. Vlach
Chairman, Science Department
Beveridge Junior High School
Omaha Public Schools
Omaha, Nebraska

Test Construction and Evaluation

Hulda Grobman
Professor of Medical Education
Center for Educational Development
University of Illinois Medical Center
Chicago, Illinois

Norman Abraham

Donald Chaney
James Campbell High School, Ewa Beach, Hawaii

Illustrations

Tak Murakami, Lake Forest, Illinois

Richard Lowe, Chicago, Illinois

Joanna Adamska-Koperska, Chicago, Illinois

Curtis Clowdus, Weaverville, California

Rand McNally & Company

William B. Miller, Director of Science and Mathematics

Nancy Lehmann Haynes, Project Editor

Roberta McAllister, Copy Editor

Susan Barnow Cohn, Designer

Julie Lundquist, Picture Editor

Foreword

During the years I have been engaged in science education, I have frequently discussed the nature and quality of instructional materials with students, teachers, and science supervisors, and have examined and evaluated many of the available texts. As a result, I am particularly pleased to see this volume and to note the authors' incisive penetration of the subject matter they consider. *Interaction of Man & the Biosphere* is an important addition to the study and communication of ecological principles, and it is especially welcome at this time.

Until very recently only a few persons could define accurately the meaning of such words as ecology, ecosystem, environment, and biosphere. Today we encounter these terms daily—in newspapers, in magazines, on the radio, and on television. They are familiar words used by individuals in virtually all segments of the population, including our legislators, local governmental officials, and politicians. Unfortunately, despite the fact that many persons recognize the words as familiar ones, too few understand their full significance.

Interaction of Man & the Biosphere will contribute greatly to correcting this situation—and correction is urgently needed if mankind is going to save much of the world we know today. We have drastically changed our world—especially in the past century. Many of the changes have resulted in dramatic improvements—physical, agricultural, medical, and social. However, some of our activities have been at the expense of much that contributes to the quality of life: clean, clear air; pure, potable water; lovely, undisturbed landscapes with abundant wildlife; and the quiet tranquillity of open space. We have sacrificed all of these in a large measure to create crowded urban sprawls connected by intertwining strips of concrete and asphalt. We have largely forgotten that *Homo sapiens* is a biological being, subject to the same needs as many other forms of life: air to breathe, water to drink, food to eat, and space to live in. We have all but forgotten that mankind is an integral part of the biosphere, interacting with other components of this environ-

ment, and that the environment is a dynamic continuum that supports and sustains all life.

This course offers students the opportunity and the guidelines for acquiring the knowledge necessary to understand their place in the biosphere and their biological heritage. From the first section, "Life in the Biosphere," to the last, "Change Through Time," students are encouraged to seek and find for themselves the information necessary to understand the role of mankind in the biosphere. Throughout the book, emphasis is placed on learning through inquiry and through verifiable observation, investigation, interpretation, and substantiation, as well as on elaboration through pertinent reading. Further, the reader is taught the necessity of using these processes to reach critical evaluations of the available data. Students frequently learn of the great movements in science—the culmination of observations or experimental work that brought pioneers in biology to new insights or discoveries. They may be asked to repeat some of their experiments or to reevaluate the reported results. Thus they develop a feeling of personal identity with the scientists and a view of the early history of the science. Students are continually challenged to think analytically, to use judgment, to search for new answers, and, perhaps most importantly, to apply or transfer their newly acquired knowledge to situations that may occur in related fields.

Students in junior high schools who are exposed to the learning experiences presented in this program will begin to develop the intellectual basis and discipline necessary for critical appraisal of many everyday problems. They will learn to formulate tentative working hypotheses, to test these in the light of additional knowledge, to determine what further information is needed to enable them to arrive at reasonable conclusions on the basis of all available evidence.

This program is an exciting exploration of the world of life around us. Students will experience broad exposure to the basic aspects of biology: the cellular nature of life; food for life maintenance and growth; internal and external control; the mechanisms of reproduction and inheritance; evolution and speciation; population structure and dynamics; organisms—their classification and names; the organization of the biosphere; and the interaction of the biosphere's components. The material is presented in a clear, thought-provoking manner and provides a close examination of familiar features of our environment as well as an introduction to entirely new and fascinating elements of the biosphere.

The five authors who comprise the writing team are all eminently

qualified: Each has a distinguished background in biological curriculum improvement as well as in the practical side of teaching biological science. Each has been a prominent member of the Biological Sciences Curriculum Study program for many years and has had experience in testing and evaluating various teaching materials and techniques. The form and content of this program is a testimony to their skills.

As with the BSCS high school texts, this publication has been tried, evaluated, and revised several times, with the assistance of many teachers, students, and educators. The result is a polished, practical guide to an inquiry-oriented life-science program.

Results from extensive classroom testing of this program as well as from the complementary ones in physical science (*Interaction of Matter & Energy*) and earth science (*Interaction of Earth & Time*) indicate that an inquiry method of teaching at the junior high school level prepares students for greater success in laboratory-oriented science courses at secondary levels and beyond. Moreover, the program serves as an excellent summation for students who do not continue their education in science. Such exposure is of great importance today, when our welfare and very survival depend upon how successful we are at solving our environmental problems. Science and technology can help to resolve some of our difficulties, but only if their capabilities are wisely used and directed.

Interaction of Man & the Biosphere will contribute substantially to awakening the interest of our young men and women in the fundamentals of ecology and in the root cause of our environmental crises. It will prepare them to participate in protecting the quality of our environment while there is still time.

JAMES A. OLIVER
Director, New York Aquarium
Formerly Director, and Coordinator of Scientific and Environmental Programs, American Museum of Natural History

Preface to the Student

You are about to begin the study of a new science course—*Interaction of Man & the Biosphere.* Methods of teaching and learning science are undergoing great changes—almost a revolution—and you are being asked to participate. Most of your class time will be spent in laboratory sessions: raising questions, observing, conducting investigations, collecting and interpreting data, and drawing conclusions that are entirely your own. In other words, most of the time you will be *doing* something rather than just reading about it or listening to your teacher talk about it. This is the way a scientist must work. If answers to all problems were known or immediately available, there would be no need for further research and investigation.

You will come to understand that science is not just a collection of facts. Rather, science is an *activity,* a continuing search for truth, with many false paths to take if one is not trained to be observant, cautious, and willing to use imagination and skill.

Science is a creative activity. For this reason, you will be working in laboratory situations that should allow you to be as creative as possible—situations that should cause you to avoid accepting something as fact just because someone said it is so.

Maintaining a careful record of your laboratory work will be an essential part of this course. Frequently you will be asked to make notes during an investigation or to organize and record data. From your notes, you should be able to interpret the results of an investigation and to predict what ought to happen if you carried out an experiment in a certain way. Scientists call such predictions "hypotheses." Forming hypotheses and testing them experimentally are among the many scientific skills you will use.

Through technology, we put to use the knowledge gained from biology and the other sciences. Exploring the moon and other planets, surveying the resources of the oceans, perfecting uses of artificial or transplanted organs in the human body—these are examples of the

achievements science and technology can bring us. We are in the habit of calling all such achievements "progress." But we are beginning to realize that some applications of technology also have unexpected and harmful effects on our surroundings.

We are entering an era in which mankind must use technology to ensure that "progress" does not destroy the plants, the animals, and the environment we depend upon for survival. In this course, you will study interactions among living things, interactions between living things and the nonliving environment, and the significance of these interactions to the continuing existence of life on this planet. Such knowledge will be needed if we are to save what is vital and beautiful on Earth—for ourselves and for future generations.

Finally, learning requires effort, but it should also provide pleasure. The authors hope you will often find enjoyment in this course and would be pleased to receive your comments at any time during your study of *Interaction of Man & the Biosphere.*

NORMAN ABRAHAM
RICHARD G. BEIDLEMAN
JOHN A. MOORE
MICHAEL MOORES
WILLIAM J. UTLEY

August 1, 1974

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The Interaction Science Curriculum Project (ISCP) is, we believe, the first curriculum project of truly national scope and size wholly funded and supported by a private publisher. It owes an enormous debt of gratitude to nearly 1500 teachers and more than 100,000 students who have participated in field testing and evaluating the Interaction Series. The series includes *Interaction of Man & the Biosphere* (IMB), *Interaction of Matter & Energy* (IME), and *Interaction of Earth & Time* (IET).

In revising IMB, the authors were guided by consultants from all areas of the country, all of whom are experienced IMB teachers. In addition, suggestions for changes were received by mail from practicing teachers and are incorporated in this revised edition.

The comments, criticisms, and suggestions from these individuals as well as from science supervisors, principals, and other educators have contributed immeasurably to this revision of IMB. Though these people cannot all be listed individually, they have our deepest thanks.

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Epilogue: Ralph Gibson for Eli Lilly and Company.

Appendix B: B · 16, B · 17, and B · 18 Norman Abraham.

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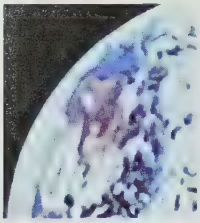
SECTION ONE

Life in the Biosphere



Do you know that you live in the *biosphere?* Perhaps you have never heard of the place before. Nevertheless, no matter where you are living now—Oahu, Ohio, Ontario, or Okeechobee—you are in the biosphere. The biosphere is that portion of the earth and its atmosphere where any form of life occurs. So you are a resident of the biosphere.

Imagine a layer of varying thickness extending over the entire earth. Its outer limit is just above the earth's surface; its inner limit is just below. Life is found within these limits—below, upon, and above the earth (Figure 1 • 1).

How far above and below the earth's surface does the biosphere extend? The upper and lower limits vary from place to place and from time to time. The boundaries of life are not fixed like the ceiling and floor of a room. In the atmosphere, tiny bacteria have been collected 9,750 m (32,000 feet) above sea level. Near Mount Everest, birds have been seen at about 8,250 m (27,000 feet). At the other extreme, life exists in many forms on the deepest parts of the ocean floor, 10,120 m (35,000 feet) below the surface. Beneath land, the limit is probably only a few thousand feet; bacteria have been found in underground water or oil deposits at such depths. As far as we know, life on Earth is confined within a very thin "skin" indeed: The earth's radius is roughly 300 times greater than the distance between the known upper and lower limits of the biosphere!

Learning something about the geography of the biosphere is interesting and useful. But much more important is an understanding of what goes on *within* it. What makes life possible?

A Way to Begin: Your Own Surroundings

Look out the window or take a walk outdoors. What do you see? There may be mountain peaks or plains in the background, rocks or soil or grass underfoot, clouds in the sky, nearby a river or lake—perhaps even an ocean. You may feel heat from the sun, be cooled by a breeze, or be caught in a shower. You may breathe pure

mountain air or be choked by smoke from a nearby factory. You may be in the middle of a desert, beside a barn, or at the foot of a 24-story building. Wherever you are in the biosphere, you will find many kinds of things making up the part of it you are in.

The nonliving things around you represent only one part of the biosphere. You help make up the other part, its living portion. There are other living things present too: trees, grass, pigeons, mosquitoes, flies, dogs, cows, and many more. Scientists call living things *organisms*. As you look about, you discover that you are sharing the biosphere with a lot of other organisms; a few are like you, but most are very different.

In this course you are going to learn about the biosphere, especially about the part of it that is alive. Later in this section you will investigate for yourself the difference between living and nonliving things. For now we will guess that you have a general idea of what is alive and what isn't. Even if organisms are very different from the nonliving *environment* (surroundings), life and nonlife are still very much tied together. The two affect each other in many ways, just as organisms affect each other in many ways. We call the relationships among organisms, and between organisms and their environment, *interactions*. In this course we will emphasize the interactions between people and the rest of the biosphere. We almost said "people and *their* biosphere," but this would be misleading: the biosphere really belongs to all the organisms that occupy it, including all human beings.

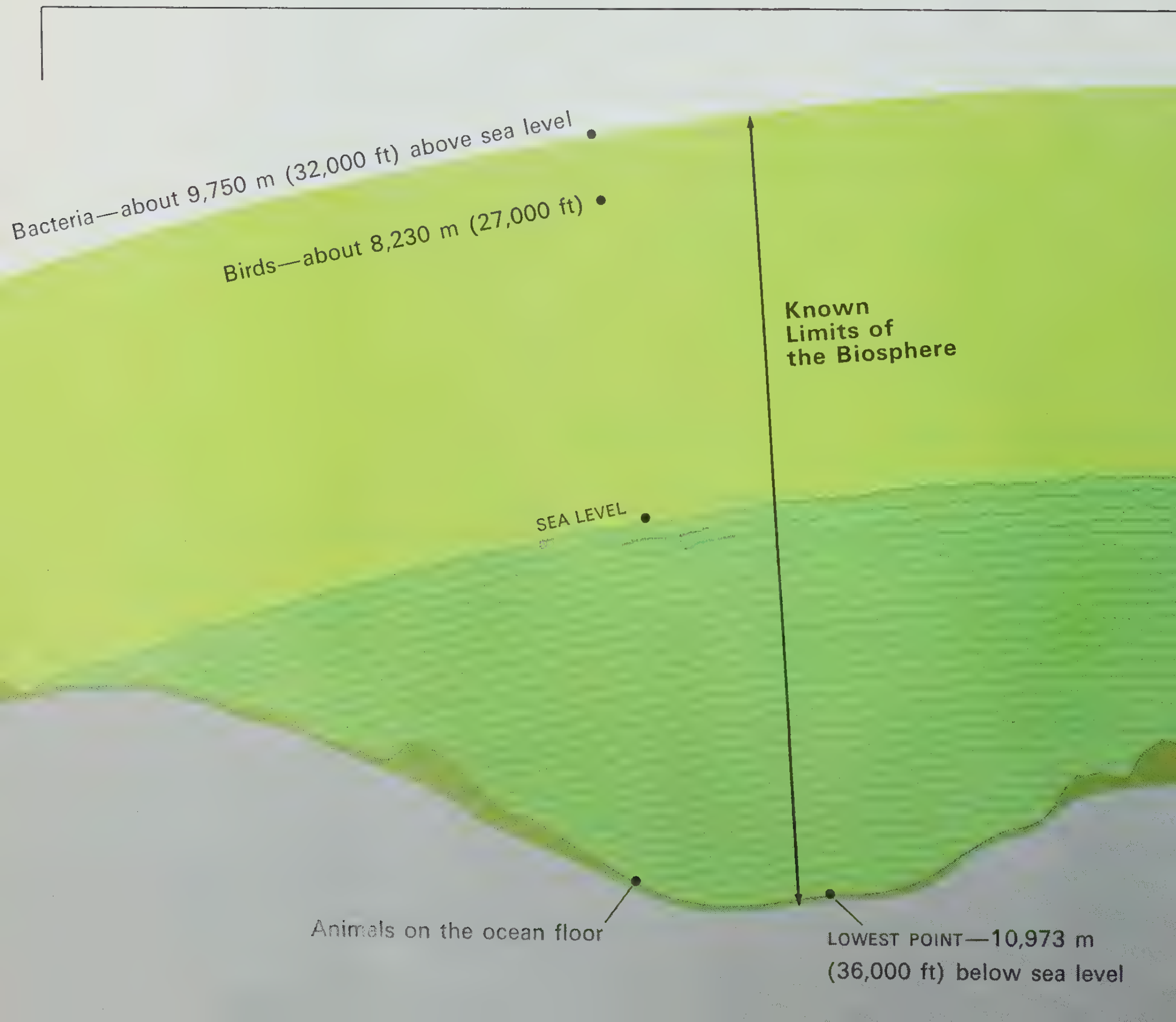
So far, you have been in school for about half your life. Perhaps much of what you have learned has simply been told to you. But we hope that in this course you will *discover* more than you are told. And a good time to begin discovering is when you begin your first investigation.

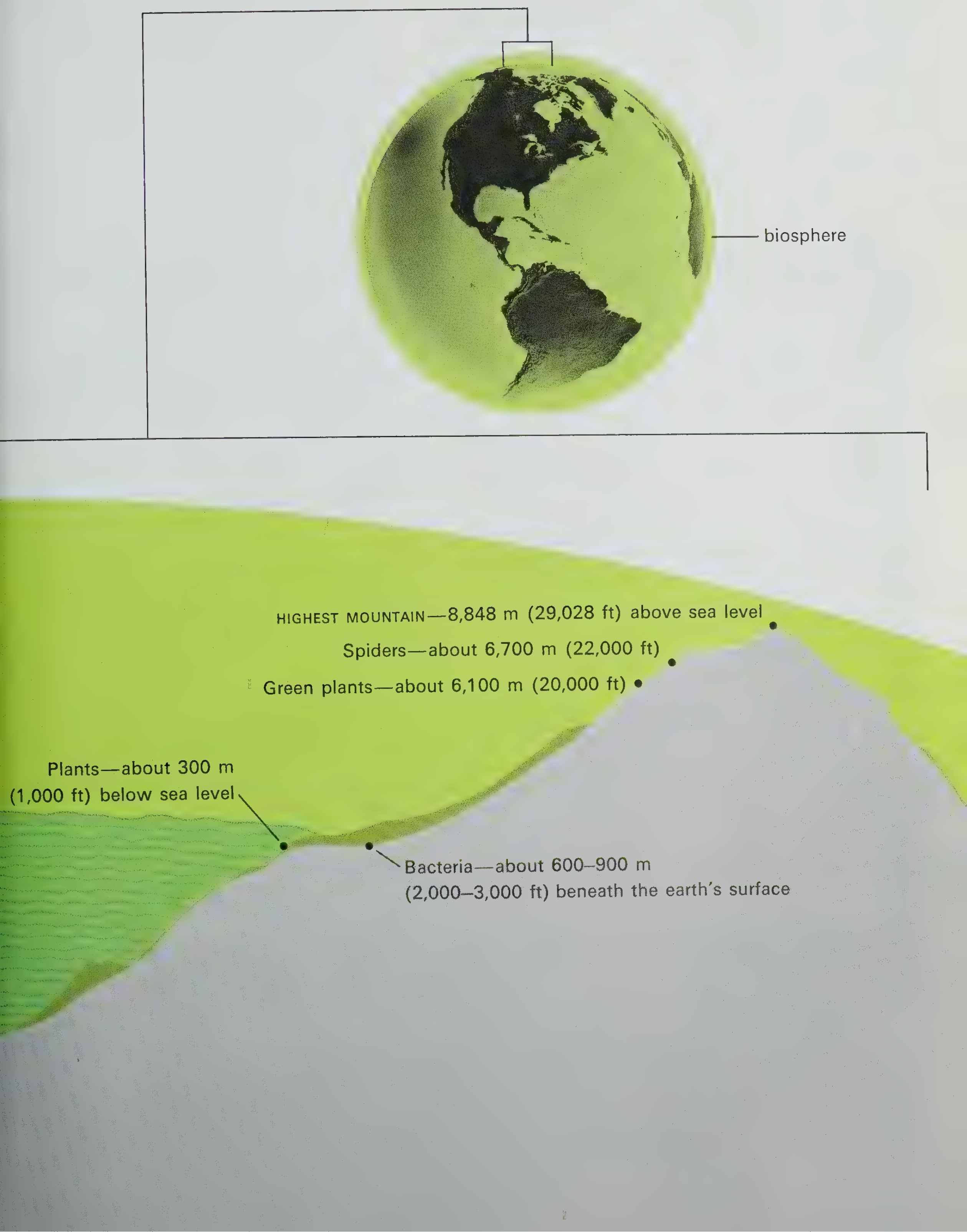
FOR CLASS DISCUSSION

1. In what way does a picture of the earth taken from space help you learn about the biosphere?
2. What additional information do you think is needed before you can learn about the biosphere?

The Extent of the Biosphere

Figure 1 • 1. A model of the biosphere (*green area*), the region in which life is known to exist, would extend over the entire globe. The biosphere's inner and outer limits are just below and above the earth's surface. At its thickest point, it is no more than 20,600 m (13 miles) deep. The known limits of the biosphere and the maximum altitudes and depths at which some kinds of organisms have been found are shown in the diagram below.

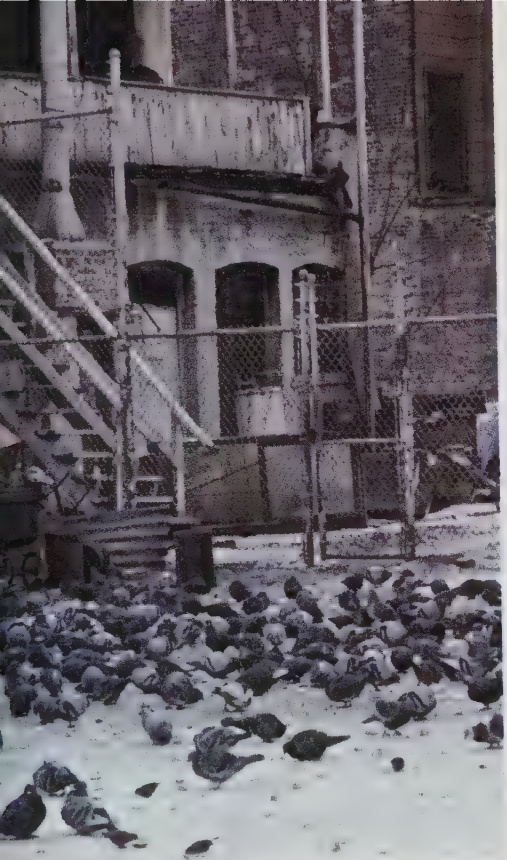



biosphere
HIGHEST MOUNTAIN—8,848 m (29,028 ft) above sea level
Spiders—about 6,700 m (22,000 ft)
Green plants—about 6,100 m (20,000 ft)
Plants—about 300 m (1,000 ft) below sea level
Bacteria—about 600–900 m (2,000–3,000 ft) beneath the earth's surface

The Variety of Life

Figure 1 • 2. Is there any place on Earth you can go without finding some form of life?

Bristlecone pine trees high in the Sierra Nevada of California



Top left: Pigeons in a city
Top right: Polar bears—North Pole
Below: Life on a coral reef being examined by a diver

ON YOUR OWN: Visiting the Environment

MATERIALS

Notebook
Pencil

PROCEDURE

Walk outside and take a careful look at the environment around where you live or where you go to school. List as many kinds of organisms as you can see—people, dogs, cats, trees, and so on. Include any evidence you find that a living thing has been there recently—bird droppings, spiderwebs, or footprints, for example. Try to identify or describe each kind of living thing you observe and record how *many* of each kind you notice. You may see evidence of interactions occurring among different living things—for example, birds eating seeds or insects. Record your observations.

Later in the course you will be asked to repeat this activity and compare observations you record then with those you record now.

ANALYSIS

1. What kind of organism seems to be most common in the area you studied?
2. Did you observe interactions occurring among organisms? If so, give examples.
3. What kind of organism appears to have the most effect on other organisms?

Getting Started in the Laboratory

You can learn about the biosphere anywhere: wandering around the streets of a city, sitting on a beach, rowing across a pond. *Biologists,* the scientists who study life, *do* work in all these places. But also, when biologists want to study things that happen in the biosphere, they often work in laboratories. There they can control such factors as light, temperature, and moisture.

Some people believe that science laboratories must contain *very* complicated equipment. In some cases such equipment is needed, but not always. It depends upon the problem being studied. You can carry out some laboratory investigations by using little more than a few jars, some household chemicals, a notebook, and an alert mind.

In your notebook keep a record of each investigation you complete. Treat the notebook carefully. Write down your observations. Keeping full records now may help you answer questions that arise later.

Laboratory work can be fun, but it can also be very discouraging. Experiments may not turn out the way you expect. You may carefully plant and water seeds that never sprout. Or you may work for weeks to raise a colony of tiny water animals, only to have them die. But you can learn to overcome these difficulties; many important scientific discoveries have resulted from experiments that "failed." For example, in attempting to produce new antibiotics, scientists fail many times before succeeding. Scientists have failed as yet to find a cure for cancer. But each failure allows them to discard one approach and directs their attention to new ideas. Scientists are much closer now to understanding the causes of cancer than ever before. Once the causes are understood, the cures should follow.

Laboratory Safety

There are some simple rules that you should always follow when you are working in the laboratory:

1. Keep your laboratory area neat and clean.
2. Do not eat any food when carrying out experiments.
3. Be very careful with all apparatus. Do not work with any instrument until you know how to use it properly.
4. If you are cut or burned, immediately call your teacher.
5. Be especially careful with chemicals. Do not taste any of them. Do not spill them on your skin, clothing, or elsewhere. If they are accidentally spilled in your eyes or on your skin, immediately wash the area thoroughly and afterward call your teacher.
6. At the end of each period, leave your laboratory area neat and clean and return all materials to their storage place. If any of your experiments are to be continued, put the materials involved in a place where they will not be disturbed.

INVESTIGATION 1.1: Interactions in a Mini-Biosphere

Three or four days from now, you will be deeply involved in your first laboratory investigation. There is a great deal of careful work that you will have to do before then. You will have to:

1. Prepare the materials.
2. Learn to use some of the instruments that scientists use.
3. Learn how to work carefully and safely in the laboratory.

MATERIALS

Clean jar, ½-pint to 1-pint capacity
Source of clean water
Dried grass
Microscope
Medicine dropper
Microscope slides, 2
Cover glasses, 2

PROCEDURES

A. Wash the jar, *thoroughly rinsing* any soap from it. In all investigations, always use clear glassware (or plastic ware).

Figure 1 • 3.
Setup for
Investigation 1.1.

B. Label the jar with your team number (or your name if you work alone) and the date.
C. Carefully remove any insects or other visible forms of life from a small handful of dried grass. Place the dried grass in the jar.
D. Add clean water to the jar until it is about ¾ full.
E. Place the jar in a place where it will not be disturbed and continue with the text.

Learning to Use an Important Instrument—The Microscope

Many things are so small that they cannot be seen without magnification. For this reason, the microscope, which can magnify objects greatly, is one of the most important tools used by biologists.

Now is the time for you to learn to use it. The necessary directions are given in Appendix A, at the back of your book.

When you have learned to use the microscope carefully and properly, examine some objects in your classroom or some that you have brought from home. A hair from your head, threads from different types of cloth, and dust from the floor should all prove interesting.

INVESTIGATION 1.1: Interactions in a Mini-Biosphere
(continued)

PROCEDURES *(continued)*

F. Without stirring the contents, hold the jar up to the light and examine it. Carefully smell the contents. Describe the odor. Record your observations.

G. With the medicine dropper, take a drop of water from near the top of the jar, at the edge. Place the drop of water on a microscope slide and cover with a cover glass. Examine under the microscope, beginning, as always, with the low-power objective. In your notebook, make a record of what you see.

H. Rinse the medicine dropper and examine water from other areas in the jar.

I. Repeat Procedures G and H at the beginning of each class period for at least a week.

ANALYSIS

1. Compare your observations with those of other students. Prepare a list of questions these observations may suggest about what is happening in the mini-biosphere.
2. You may have seen small objects moving around in the water. Knowing that only water and dried grass were put into the jar, where do you think the objects came from?

ON YOUR OWN: Source of Organisms

PROCEDURES

Assume that the small, moving objects in your mini-biosphere are living. Design and carry out an experiment to find the source of the organisms. Write a brief statement about what you think the source is and how you plan to set up your experiment. Show your paper to your teacher *before* you proceed with the experiment.

ANALYSIS

Interpret the results of your experiment and write a brief statement saying what you think the source (or sources) of organisms in your mini-biosphere is and why you think so.

ON YOUR OWN: Comparing Organisms in Fresh and Polluted Water

PROCEDURES

A. Collect samples of stagnant or polluted water.
B. Collect samples of fresh water from a stream, pond, or lake.
C. Using Appendix H, try to identify some of the organisms you collected.
D. Compare these organisms with those you found in your mini-biosphere.

ANALYSIS

1. How do the kind and number of organisms you found in fresh water compare with the kind and number you found in stagnant or polluted water?
2. How do the kind and number of organisms you found in your mini-biosphere compare with the kind and number you found in natural water environments?

Learning About Nature

Scientists are people who study nature. Biologists are scientists who study living nature—animals and plants. They seek to understand such things as how people's hearts beat, how people grow, how young are born, the diseases that make people sick, the kinds of animals and plants that are found in various parts of the world, how to grow more food, and the kinds of things that you observed in those drops from the jar containing dried grass and water.

How do scientists learn about these matters? There is no single way or single "scientific method"—but many scientists follow a pattern somewhat like the following:

1. They observe something that interests them.
2. They ask questions.
3. They talk to one another and read about what they have observed.
4. They try to answer a question by making additional observations and, in some cases, by conducting experiments.
5. They suggest to other scientists what they think the answer is.
6. Other scientists review the observations and the experimental results and then decide whether or not they think the suggested answer is correct. If they do not think it is correct, they may make more observations and try different experiments.

You have already done some of these things with the jar of grass and water. You have made observations (No. 1); you have discussed your observations with other students (No. 3); you have tried to answer a question (No. 4).

There is one other important thing that you have done. You have asked questions about what you observed in the jar (No. 2). Either members of your team or other students probably saw moving objects in the drop of water taken from the jar. Some of you may have suggested that the moving objects are alive. Others may not have thought so. An important question, therefore, could be: *Are the moving objects alive?*

How could you answer this question? First you would have to decide what is meant by the word "alive." That is, what are the characteristics of living things? This is a matter that you should discuss with other students and with your teacher. One way you could begin is to think about several kinds of living things. Then ask yourself what they have in common. Do they all have heads, or move, or eat, and so forth? When you have made the list, use it to determine whether or not any of the moving objects are alive.

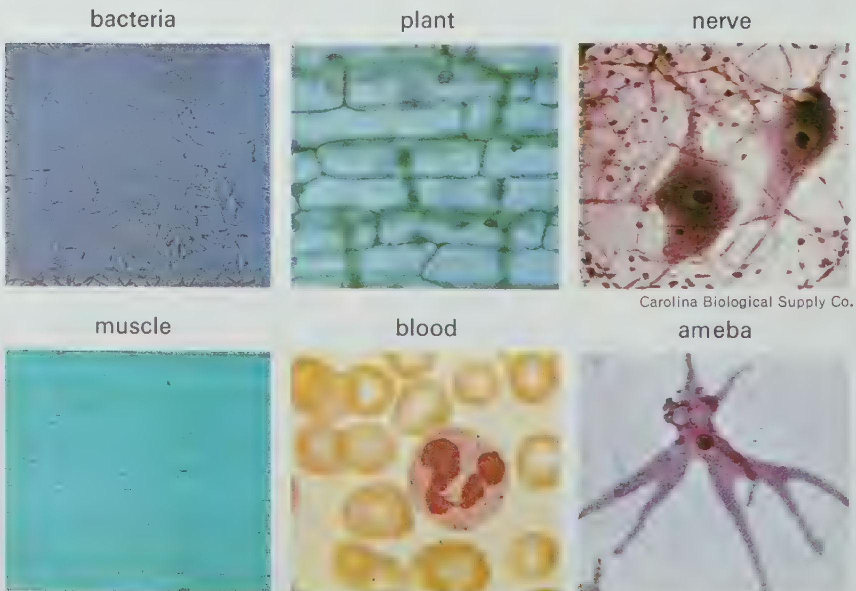
In deciding, try to list, in your notebook, some activities and characteristics of living things.

In completing your list, you might wish to consider a few questions about yourself: What do you breathe? What do you eat? If part of your food is made up of other animals, what do *they* eat? If they eat plants, what do plants eat?

About Cells

In the mid-1600's, Robert Hooke, an English scientist, viewed thin slices of cork through his microscope. Much to his surprise, he observed that the cork material was not solid. Instead, it was made up of adjoining hollow compartments surrounded by very thin walls. He called these small compartments "cells." Since that time many other scientists have studied the microscopic structure of different kinds of organisms. After almost 200 years of study by many researchers, scientists concluded that all living things are made up of cells.

Some organisms consist of but a single cell (Figure 1 • 4: ameba and bacteria). Many of the organisms you observed in the grass-water mixture are single-celled organisms. However, most living things large enough to be seen without a microscope consist of many cells. You are made up of many billion cells! What do your cells look like? There is no one answer, for your body consists of many different *kinds* of cells—bone cells, skin cells, brain cells, and so on. It is like asking, What do plants and animals look like? Just as there are many different kinds of plants and animals,



Carolina Biological Supply Co.

Carolina Biological Supply Co.

Figure 1 • 4. Variety in cell structure.

there are also many different kinds of cells. Cells vary greatly in shape. Some are round. Others are shaped like boxes. Still others may be long, cigar-shaped objects. Some cells are able to move from place to place. Other kinds may remain in one place, unable to move about. Still other kinds may move because they are carried along by the fluid in which they are found. A few kinds change shape as they move. Others, such as nerve cells, may have long branches extending from them. The variety of cells seems endless. Almost every cell, however, consists of a fluid interior surrounded by an outer membrane. This membrane is so thin that it cannot be seen with an ordinary microscope. In the next investigation you will become better acquainted with the structure of some kinds of cells.

INVESTIGATION 1.2: Comparing Cells

One difficulty in seeing cells through a microscope is that light must pass through the materials you are viewing. For this reason very thin, transparent pieces of a plant or animal must be used. This investigation is not easy to do. But if it is successful, you should be able to see different kinds of cells.

MATERIALS

- Microscope
- Microscope slides
- Cover slips
- Water-plant (elodea) leaf
- Methylene-blue stain or IKI solution
- Toothpicks
- Medicine dropper
- Forceps
- Light source

PROCEDURES

A. Place a drop of water on a clean slide. Place a small leaf from the growing tip of an elodea shoot in the drop. Add a cover slip.

B. Examine the elodea leaf, using the 10 X objective (low power) of the microscope. Locate some cells that appear to be less green than other cells in the leaf and center them in the field. Switch to high power, being careful not to lower the objective lens onto the cover slip. Describe and sketch some elodea cells.

C. Remove the slide and gently warm it for about ten seconds over a light bulb. Replace the slide on the microscope stage and carefully observe the contents of the cells. Do you see anything happening inside the cell? If not, try warming the slide and observing again.

D. Place a drop of methylene-blue stain (or IKI solution) on a clean slide. With a sterile toothpick, *gently* scrape the *inside* surface of your cheek. Carefully stir the cheek material into the drop of stain. Add a cover slip and view the preparation microscopically under the 10 X objective. Then switch to high power and observe. Describe and sketch cheek cells.

ANALYSIS

1. Describe what seems to be the major difference between an elodea (plant) cell and a cell taken from the inside of your cheek. What are the similarities?
2. What difference in function might account for the difference in structure between elodea cells and cheek cells?

FOR FURTHER ACTIVITY

Gather several different kinds of green leaves and look for cells. You cannot place a whole leaf under the microscope and expect to see cells as you did with the elodea. Not enough light can penetrate the leaf. Tear a leaf and, grasping the torn edge with forceps, carefully peel away a very thin piece of the outer layer. If the piece is thin enough, you should be able to see cells. How many different kinds of cells can you find?

INVESTIGATION 1.3: Another Biosphere?

So far in this course you have studied a variety of living things. You have seen some examples of cells—the basic units of life as we know it.

At this time Earth is the only sphere, among the billions of spheres that exist in the vast universe of stars and planets, known to support life. But if you view the night sky and let your mind wander a bit, you may think that surely, somewhere in outer space, there must exist another biosphere—a sphere containing living things.

Imagine that you are a member of a team of scientists that has just landed on Planet X. You want to determine whether or not there is life there. If there is, Planet X represents another biosphere.

You find that you can leave the spacecraft and breathe the planet's air without trouble and that there is a stream nearby. In these respects, at any rate, the new planet is very much like your own biosphere. Each member of your team spends several days exploring the area without finding any green plants, moving animals, or other signs of life. But you do collect five different kinds of strange materials. Your task is to determine whether or not any of the materials collected on the planet are living. How would you do this?

Your laboratory investigation will be to determine if any of five materials are alive.

NOTE: *Do not taste any of the materials. You do not know whether or not they are poisonous.*

MATERIALS

Samples of 5 unknown substances (provided by your teacher)
Hand lens
Some chemicals (provided by your teacher)
Miscellaneous glassware
Heat source
Paper cups

PROCEDURES

A. Make a list of the ideas you plan to use in deciding whether the materials are living or nonliving.

B. In your notebook copy the chart in Figure 1 • 5 but make it larger than it is in the book so you will have plenty of space in which to write. Label each material sample with a number. Using a hand lens, examine each of the materials. In your chart, record what each looks like. Under the column headed "Your Prediction," place a check mark to indicate whether you think the unknown is living or nonliving.

Figure 1 • 5.

Unknown Number	*Description (color, shape, odor, size, etc.)*	*Your Prediction*	
		Living	*Nonliving*
1			
2			
3			
4			
5			

C. Plan several methods that might allow you to find out which of the unknown materials are alive. For example, you might do the following:

1. Place water on each unknown material and see if anything happens.
2. Examine each unknown material under a microscope.

Whatever methods you choose, keep a careful record of what you do and of what results you obtain.

D. Your investigation may take several days. When you have finished, report your discoveries to the class.

ANALYSIS

1. Were you able to predict which of the unknown materials are alive?
2. Have you proved that some of the unknown materials are *not* alive?

The Biosphere in Trouble

Although you encountered no human beings on Planet X, suppose you saw things that suggested the presence of people like ourselves on that strange planet? What if you saw a pile of rusty tin cans, or windblown candy wrappers, or a wrecked automobile? What if you found air polluted with black smoke and carbon monoxide fumes, or a stream filled with sewage and trash? What if you discovered the remains of a forest of gigantic trees, with only the stumps remaining? What if you walked past row after row of empty buildings and found no people? What if you found gigantic reservoirs that were nothing now but mud flats, or abandoned farmland that was either deep in fine dust or covered with white salt?

If you found any or all of these things on Planet X, you would suspect that at some time in the past people had lived there—because only human beings, among all the living things we know, leave behind such traces of their activity.

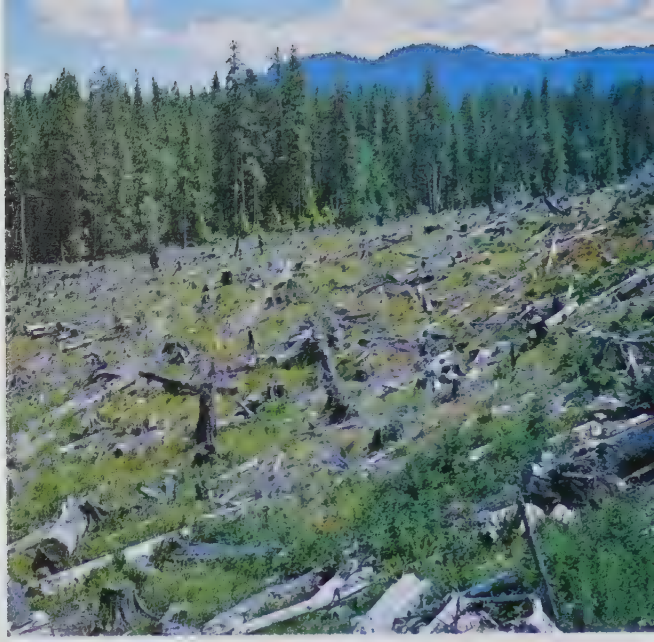
People have created many beautiful and useful things, as we know from experience in our own biosphere. But as our numbers have increased and life has become more complex, the problems we have created in the biosphere have multiplied tremendously. We read today about these problems in magazines and newspapers, hear about them on radio, and see them portrayed on television. Indeed, if we are observant, we can recognize in our own communities many of the difficulties associated with the human impact on the biosphere.

How will these problems be solved? What can you do to help? What should industry and government do to help? Some people hope that the problems will simply go away. Other people think they have quick and easy answers to all the problems concerning the biosphere. But as we have noted, the biosphere exists because of a delicate balance between organisms and their environment. When this balance is upset, both life and the nonliving environment may be harmed.

Learning to understand the complex interactions between life and the environment is what *Interaction of Man and the Bio-*

Planet X

Figure 1 • 6. Imagine yourself as a visitor to Planet X. What impressions would these scenes make on you? How did the former inhabitants probably feel about their environment?



sphere is largely about. Section Two deals with a very vital interaction—the one between green plants and their environment. Sections Three through Five show how human life is completely dependent upon this interaction; they should provide background to help you understand the sections that follow—sections that focus on major problems that all of us face.

FOR CLASS DISCUSSION

1. Do you think it possible that, in fifty or a hundred years, Planet X could really be the planet Earth—its visitors coming from some other planet in the universe?
2. If your answer to Question 1 is yes, give reasons. What do *you* think people should do to prevent the planet Earth from becoming like Planet X?

Extending Your Knowledge

1. You may have heard the story about the four blind men who tried to describe an elephant. One of the men felt its side—and described the elephant as being like a wall. Another felt its leg and described it as being like a tree trunk. After feeling its trunk, the third man said the elephant was like a large snake. The last man felt its tail and pictured the elephant as a rope! Each man described well what he felt. But none of them, on the basis of one experience, could picture the whole animal.

   A similar difficulty will arise if you are asked to describe a seashore. Some of you may never have been to a seashore. But you might still imagine what seashores are like from seeing pictures of them or reading about them. If you actually have visited a seashore, your ideas about it may still differ from other people's ideas. You may have been to a sandy beach, whereas a friend has only been to a rocky beach. Or maybe the one seashore you have experienced was a mud flat in which your bicycle got stuck.

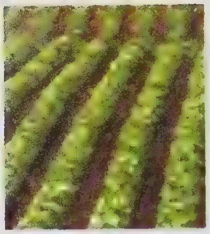
   Describing an elephant or a seashore is difficult enough. What do you think would be necessary before a person could describe the biosphere?
2. In the Pacific Northwest there is a kind of sparrow that lives in bushes. In a city in that part of the country, a man who disliked sparrows had a large backyard in which there were some wild bushes—and a large number of sparrows. He wanted to get rid of the sparrows, but it was against the law in the city to kill them. How could he get the sparrows out of his backyard without hurting any of them?
3. State and federal laws have been passed that require automobiles to have emission-control devices installed on them. These devices reduce the amount of chemicals, which are released in auto-exhaust fumes, that cause air pollution. A side effect of the devices is that gasoline mileage is reduced. That is, an auto with the emission-control device requires more gasoline to travel a given distance than one without the device. On the other hand, many people are concerned about

the increasing rate at which we are using up the oil supplies of the world. Oil, of course, is the source of gasoline needed to run automobiles. Which do you think is more important, reducing air pollution or efficient use of oil supplies? Is there another choice?

4. The Panama Canal, by means of a series of locks, rises from the salty Atlantic Ocean to a large, man-made, freshwater lake, Gatun Lake, and then descends to the salty Pacific Ocean. There have been plans for a new canal to be built at sea level, which would provide a direct saltwater contact between the Atlantic and Pacific. The Pacific side is colder and has higher tides than the Atlantic side. Also, there are shrimp and mackerel fisheries on the Pacific side but not on the Atlantic side. Why might some marine biologists be worried about the development of this new sea-level canal to take the place of the old canal?

SECTION TWO

Investigating an Interaction



When we mention the word "interaction," you may have a shadowy picture of hundreds of little organisms moving around in your mini-biosphere. But "interaction" means more than just movement.

It includes all the different ways organisms affect each other, how they affect their environment, and how the environment affects them. As you might guess, interactions are complex. Scientists often gain knowledge about the biosphere by studying a single interaction at a time. As knowledge of different interactions accumulates, an understanding of the biosphere as a whole begins to emerge.

You are about to focus your attention on one interaction—the interaction between green plants and their environment. One of its results is the production of food materials needed for plant growth. As you study this interaction, consider not only *what* is discovered but also *how* it is discovered.

You can probably think of several things in the environment that influence plant growth. Many of these things affect plant growth because they affect the process of food production called *photosynthesis.* Photosynthesis is the process by which green plants make sugar. In most green plants the sugar is then changed to starch. Sugar and starch are the basic food materials that plants use for growth.

In your notebook make a list of things that you think might be involved in this interaction between green plants and their physical environment. How could you determine which things are necessary and which are not necessary for photosynthesis to occur? For example, suppose that light is the first item on your list. How could you find out if light is needed for photosynthesis? Carrying out the following investigation is one way you might find out about the role of light in photosynthesis. The plan of the investigation is based on the following ideas:

1. First we remove one thing from the plant's environment (in this case, light) that we think might be important in photosynthesis.

2. If we find that photosynthesis still occurs, the thing removed probably was *not* involved. If photosynthesis does *not* occur, then the plant probably needs that thing to carry on photosynthesis.

INVESTIGATION 2.1: Light and Green Plants

MATERIALS

Geranium or bean plant with large leaves
Aluminum foil
Scissors
Heat source
600-ml beaker
250-ml beakers, 2
Small dish
Alcohol solution
IKI solution (iodine–potassium iodide solution)
Forceps
Light source

PROCEDURES (Day 1)

A. Cut out a square of aluminum foil about 15 cm on a side and label it with your name or team number.
B. Completely cover one leaf of the test plant with foil so that no light can reach the leaf surfaces.

NOTE: *The test plant has been kept in the dark for three days.*

C. Place the plant under a light source and leave it for two days.

While you are waiting for results to occur, consider the following questions: How can you tell if photosynthesis is occurring in a plant? Why must you be able to answer that question before you can determine what role light plays in photosynthesis?

Carry out Investigation 2.2, "Testing for Starch and Sugar."

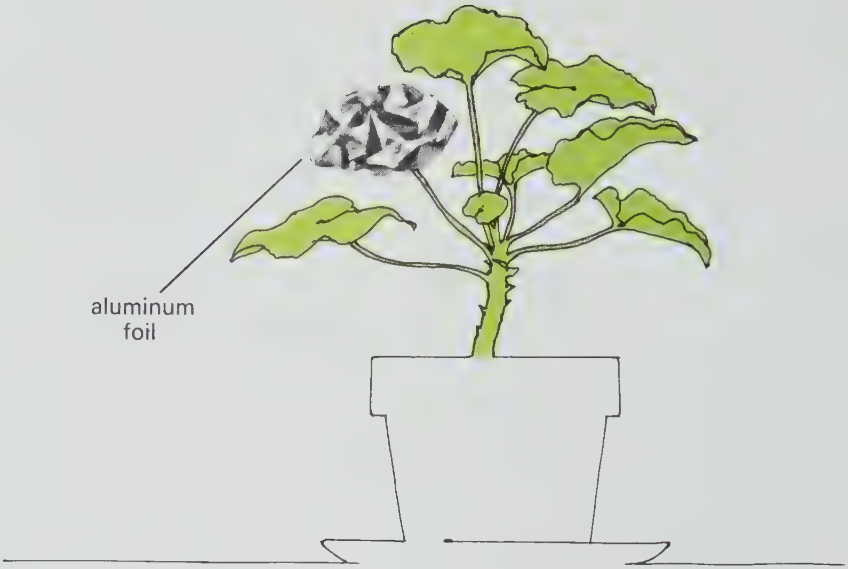


Figure 2 • 1. Geranium plant, one leaf covered with foil.

The techniques described in that investigation should give you a clue about one way to find out if a plant is carrying on photosynthesis.

PROCEDURES (Day 3)

D. On Day 3 remove an *uncovered* leaf from the plant. Place the leaf in boiling water for one to two minutes. Remove the leaf from the water with a pair of forceps and place it in a hot alcohol solution. When the leaf has lost its green color, remove it from the solution.

CAUTION: *The vapors of boiling alcohol are flammable. Heat the alcohol in a water bath. Don't inhale the alcohol vapor.*

E. Dip the leaf back into the boiling water. Then place the leaf flat in a small dish and flood it with IKI solution. After three minutes, record your observations.

F. Remove the foil from the leaf that was covered. Repeat Procedures D and E with that leaf.

ANALYSIS

1. What did the tests indicate was present in the uncovered leaf? In the leaf that was covered?
2. What was the purpose of covering one of the leaves?
3. What was the purpose of testing an uncovered leaf?
4. Assume all green plants carry on photosynthesis in the same way as the plant you used in this investigation. Judging from the results of this investigation, name one environmental factor needed for green plants to carry on photosynthesis.
5. An *equation* is a brief statement made up of symbols, numbers, or words often used to show how certain interactions occur. Using words, fill in the blanks in the following equation. (It should describe what you have just learned about photosynthesis.) Copy the equation in your notebook. Do not write in your textbook.

$$\text{green plants} + \underline{\quad ? \quad} \xrightarrow{\text{(produce)}} \underline{\quad ? \quad}$$

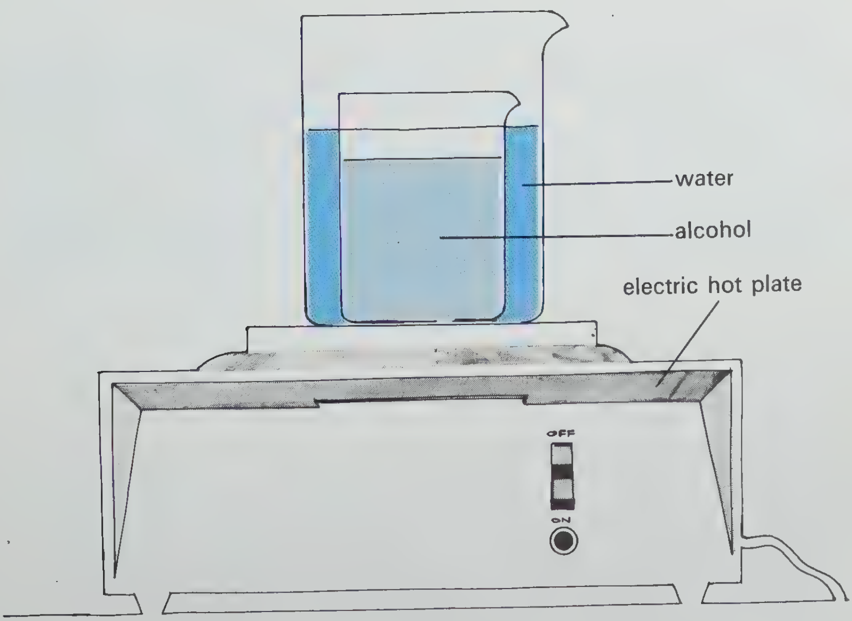


Figure 2 • 2. Heating alcohol in a water bath.

INVESTIGATION 2.2: Testing for Starch and Sugar

A positive sugar test indicates that sugar is present. A positive starch test indicates that starch is present. Negative results with both starch and sugar tests indicate that neither is present.

MATERIALS

- Benedict's solution
- IKI solution
- 600-ml Pyrex beaker
- Graduated cylinder
- Heat source (Bunsen burner, alcohol lamp, or hot plate)
- Test tubes, 2
- Test-tube holder
- White Karo-syrup solution
- Various foods (bread, potato, milk, cornstarch)

PROCEDURES

Sugar Test

A. In your notebook copy the following chart:

Figure 2 • 3.

	Sugar Test	*Starch Test*
Karo syrup		
Bread		
Potato		
Milk		
Cornstarch		

B. Using the graduated cylinder, measure out about 5 ml of white Karo-syrup solution and pour it into a test tube. Add about 5 ml of Benedict's solution.

C. Place the test tube in a boiling-water bath (see Figure 2 • 4).

D. As soon as a definite color change occurs, remove the test tube from the beaker. A color change to green, yellow, or red indicates that sugar is present. Test other foods provided by your

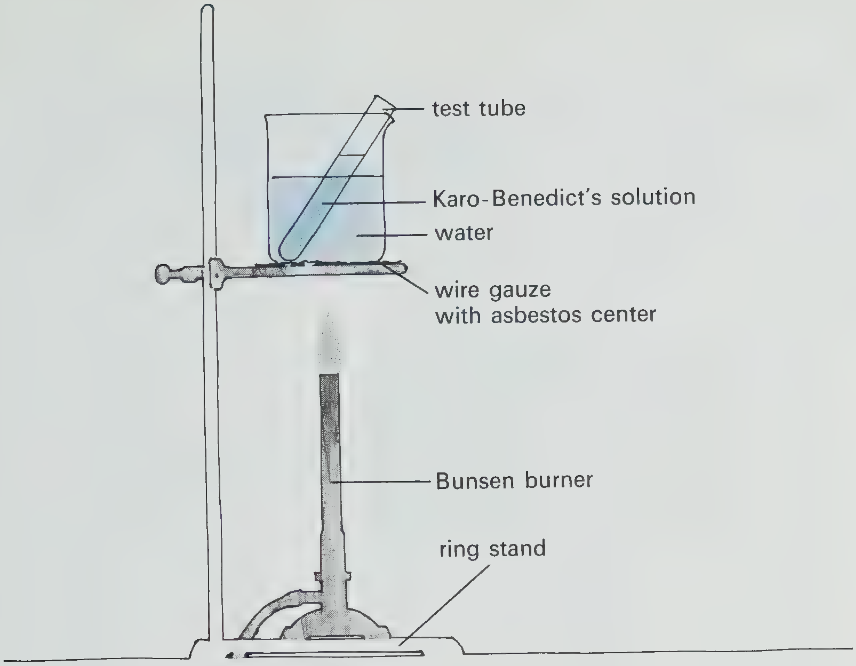


Figure 2 • 4. Setup for Procedure C.

teacher to see if they contain sugar. If a food is solid, break it up into small pieces. Add a small amount of water and Benedict's solution. Heat the mixture as you did in Procedure C.

If a food has sugar in it, write a plus sign (+) in the proper space under "Sugar Test" on your chart. If it does not, write a minus sign (—) there.

Starch Test

E. Place a pinch of cornstarch in a clean test tube. Add water until the test tube is about ¼ full. Carefully stir the mixture.

F. Add 4 or 5 drops of IKI solution. **Do not heat.** In your notebook record the color change. A blue-black color indicates starch.

G. Test for starch in Karo syrup, bread, and the other foods provided. Record the results of each test. If the food has starch in it, put a plus sign (+) in the space under "Starch Test." If it does not, write a minus sign (—) there.

INVESTIGATION 2.3: Testing an Idea

In Investigation 2.1 you should have developed an idea about the role of light in the process of photosynthesis and starch production in green leaves. In this investigation you will attempt to verify (support) your idea by working with leaves that are not exposed to light.

MATERIALS

- Beakers or baby-food jars, 2
- Scissors
- Healthy geranium plant that has been kept in darkness for 48 hours
- 5% sugar solution
- Water bath
- Alcohol
- Flat dish
- IKI solution

PROCEDURES

A. Fill one of the containers with water and label it *water*. Cut one of the leaves with petiole attached (see Figure 2 • 5) from the geranium plant. Place the cut end of the petiole in the water. If the petiole will not stay in place, you may have to support the leaf on an inverted container placed beside the one filled with water.

B. Fill another container with 5% sugar solution and label it *sugar*. Remove another leaf from the geranium plant and place its petiole in the sugar solution.

C. Place both containers and leaves in a dark cupboard or cover them with a box.

D. After 24 to 48 hours, test both leaves for starch as you did in Investigation 2.2. Identify the leaves by cutting a notch in the leaf kept in the sugar solution.

E. Observe each leaf carefully. Make notes and sketches indicating any areas of starch production.

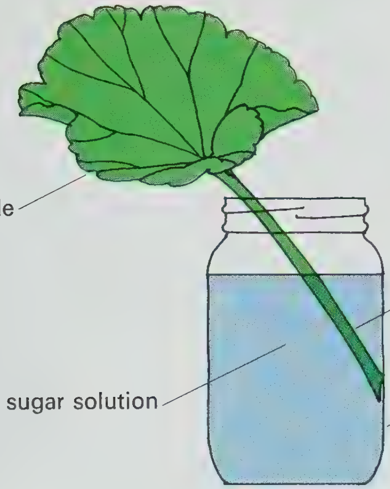


Figure 2 • 5.
Setup for Procedures A and B.

ANALYSIS

1. Is light necessary for starch production in geranium leaves? Explain in terms of the results of this investigation.
2. Do the results of this investigation support your conclusion made in Investigation 2.1? Explain your answer.

HINT: *Do you think the substance produced during photosynthesis is starch or sugar?*

INVESTIGATION 2.4: More About Photosynthesis

As you begin this investigation, predict what substance of importance in photosynthesis is being studied.

MATERIALS

IKI solution
Aluminum pie pans, 2
Gallon jars or other large glass containers, 2
Healthy potted bean or geranium plants, 2
Small beakers or baby-food jars, 2
Small dish
600-ml beaker
250-ml beakers, 2
Concentrated sodium hydroxide solution
Light source (150-watt bulb and socket)
Heat source
Alcohol solution
Forceps
Cloth or paper wick

PROCEDURES (Day 1)

A. Place the plants in the pie pans. Invert a gallon jar over each plant. Label the jars A and B (see Figure 2 • 6). The plants were kept in the dark three days prior to the start of the experiment so starch reserves in the leaves would be used up.

B. Under Jar B, place a baby-food jar containing 50 ml of water. Under Jar A, place a baby-food jar containing 50 ml of sodium hydroxide solution.

CAUTION: *Sodium hydroxide is caustic. Do not spill any or get it on your clothes or skin.*

Sodium hydroxide will remove carbon dioxide from the air in Jar A. Place a cloth or paper wick in each solution, as shown in Figure 2 • 6.

C. Place Jar A about 20 cm to the left of the light source, Jar B about 20 cm to the right (as in Figure 2 • 6). Partially fill each

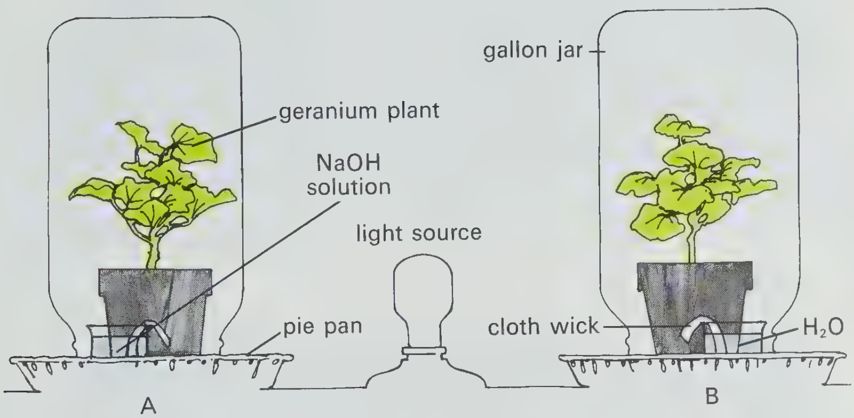


Figure 2 • 6. Setup for Procedures A–C.

pie pan with water to form an airtight seal. Let the setup stand for two days.

While you wait two days for results to occur, study "About Experimental Biology," pages 39–41, and carry out the discussion activities listed on pages 41–43.

PROCEDURES (Day 3)

D. Remove one leaf from Plant A and one leaf from Plant B. Label each leaf.

E. Test each leaf for starch.

ANALYSIS

1. What difference, if any, did you notice between the results of the starch tests with the two leaves?
2. What is the reason for placing a jar of water under Jar B?
3. In Investigation 2.1 you wrote a brief word equation describing photosynthesis. Rewrite that equation, adding new information discovered from Investigation 2.4.

green plants + ___?___ + ___?___ (produce) ⟶ ___?___

Figure 2 • 7.
In 1760 George Washington conducted the controlled experiment illustrated above.
A. Shows what was mixed with soil in each row.
B. Shows the results after two weeks.

About Experimental Biology

Defining "Hypothesis" and "Theory"

The word "hypothesis" is used very often in science. Sometimes a hypothesis is defined as an "educated guess." All of us wonder about various things, guess, and have hunches. You may wonder what you will have for dinner or guess that a particular person doesn't like you or have a hunch that it will rain tomorrow. When a scientist talks about a hypothesis, he or she does not mean just a guess or a hunch. Before stating a hypothesis, a scientist usually (1) wonders about something; (2) searches for what other scientists have written about it; (3) asks one or more questions; and (4) makes a number of observations. He may also carry out preliminary investigations. When he feels fairly certain that his idea and his observations are correct, he then may state his idea in the form of a hypothesis that can be tested. The test can be by observation or experiment. A hypothesis, therefore, is an explanation of something that can be tested.

If after careful testing he observes that his hypothesis *appears* to be correct, he may publish the results of his experiment in a book or journal. Other scientists may try the same experiment and obtain the same results. After many observations and experiments by many scientists, over a long period of time, and with the same results, the hypothesis may be considered "true beyond all reasonable doubt." Sometimes it seems so well verified that we call it a law. The law of gravity is an example.

The term "theory" is often used for a general principle derived from a body of related knowledge. Thus lots of different observations and experiments have been made about the structure, composition, and function of cells. From this information the cell theory has been formulated.

Use of Controls in Experimental Work

In order to search for reasonable answers to some questions, it is necessary to carry out experiments. There are several major problems to be considered before an experiment is started. First, the question to be asked must be one that has a *reasonable chance* of

being answered. For example, suppose you ask the question: How much do fish weigh? Unless this question is reworded, you cannot answer it. It would all depend upon the fish being weighed. What kind of fish? How old? Have they been fed? Suppose the question were changed to: How much will 50 rainbow trout weigh one year after hatching if fed all they will eat? You now have a better basis for conducting an experiment and a reasonable chance of finding a meaningful answer.

Certain experiments require the use of *controls*. A controlled experiment actually has at least two parts: one part may be called the test, the other the control. Consider the following example: What conditions are necessary for radish seeds to sprout and become radish plants? You might think that radish plants would grow best if they were kept moist. So you suggest the hypothesis that radish seeds must have water in order to sprout. Then you plan and carry out an experiment to test your hypothesis. Ten radish seeds taken from the *same* package are planted in each of two glass dishes. Both dishes should contain the *same* kind of soil, and the seeds are planted at the *same* depth in both. One dish is labeled Dish A, the other Dish B. Both dishes are placed side by side on the *same* shelf. Water is added each day to Dish A, but none is added to Dish B. After one week the two dishes are examined. In Dish A nine radish plants are observed. In Dish B no radish plants are observed. In this experiment Dish A (the one watered) is the test, Dish B the control.

The results indicate that the hypothesis you proposed is probably correct. But what if there had been no Dish B? Could you have reached the same conclusion? Without the use of a control, you could not have been sure that the seeds would sprout regardless of whether water was added. By using a control, you could *compare* the results observed in the two dishes and, on this basis, reach a reasonable conclusion. It was important to use the *same* kind of soil, place the *same* number of seeds in each of the two dishes, plant the seeds at the *same* depth, and place the dishes in about the *same* place.

The word *same* is very important in understanding the idea of

controlled experiments. An ideal controlled experiment is one in which all conditions are the *same* for both the control and the test *except for* the one specific thing being tested. (In actual practice, however, it is almost impossible to keep *all* conditions *exactly* the *same* for both control and test.) The hypothesis about radish seeds involved only the role of water. Other possibilities (hypotheses) that were not tested (but could be) include the effect of heat, light, time of year, kind of radish seeds.

Not *all* scientific work must be carried out in laboratories or necessarily involve experiments. For example, a great deal has been learned about weather, volcanic activity, and animal behavior by observing these things in the field.

FOR CLASS DISCUSSION

Here are descriptions of four different experiments that may or may not fit the definition of "controlled experiments." In each case there may be one or more conditions that are *not* controlled. See if you can locate possible "errors" (if any) in each experiment or in the interpretation of the results. Then describe how you would change each experiment so that it can correctly be called a controlled experiment. In each case the hypothesis may be correct, but not necessarily supported by the experiment. You may wish to perform the first two on your own.

When you have carefully considered each of the four experiments described below and on page 42, you might design several more that illustrate the same points. You might also discuss your experimental designs with other students in your class and criticize each other's work. Constructive criticism is a major part of scientific work.

Experiment 1

Hypothesis:	Light is necessary for green plants to be green.
Procedures:	A bean plant that was growing in sandy soil was kept in the dark for five days. A tomato plant that was growing in garden soil was kept in the light for five days.
Results:	After five days the plant kept in the dark had

	lost most of its green color and had yellow-colored leaves. The plant kept in the light remained green.
Analysis:	The hypothesis is correct.

Experiment 2

Hypothesis:	Detergents in water will destroy living things.
Procedures:	A teaspoonful of detergent was added to an aquarium containing five guppies.
Results:	Within three days all the guppies died.
Analysis:	The hypothesis may be correct.

Experiment 3

Hypothesis:	If people drink polluted water, they will become ill.
Procedures:	A group of three people drank polluted water. Another group of three people drank water that was not polluted.
Results:	All three people who drank polluted water became ill. None of those who drank unpolluted water became ill.
Analysis:	The hypothesis appears correct, but further investigation is needed.

Experiment 4

Hypothesis:	The length of daylight affects loss of leaves in maple trees.
Procedures:	One thousand five-year-old maple trees were transplanted into two greenhouses. Five hundred of the trees were exposed to short "daylight" hours; 500 were exposed to long "daylight" hours. The trees in both greenhouses were grown under identical conditions. The only thing that varied was the length of "daylight."

Results: The trees in the greenhouse with short "daylight" hours had all lost their leaves in October. By the middle of November, the trees in the greenhouse with long "daylight" hours still had most of their leaves.

Analysis: The hypothesis appears to be correct.

INVESTIGATION 2.5: Location of Starch in a Leaf

The green substance in plants is *chlorophyll.* Some plants have variegated leaves—leaves with more than one color. In this investigation you will examine photographs of variegated geranium leaves that should add to the information you have about photosynthesis.

PROCEDURES

A. Describe the color distribution in a variegated leaf from a geranium plant.

B. Describe the way starch is distributed in a variegated leaf.

Figure 2 • 8. Locating starch in a leaf.
A. Fresh. **B.** With chlorophyll removed. **C.** After IKI is added.

ANALYSIS

1. What substance in the geranium leaf appears to be necessary for starch production?
2. Rewrite the following equation, adding new information you have gathered about photosynthesis:

$$\text{green plants} + \underline{\quad ? \quad} + \underline{\quad ? \quad} + \underline{\quad ? \quad} \xrightarrow{\text{(produce)}} \underline{\quad ? \quad}$$

3. In the fall, some leaves may turn red—others yellow. Would you expect to find starch in these leaves? Explain your answer.

Figure 2 • 9. A New England forest in the fall.

The Final Ingredient

Scientists have known for some time that oxygen and carbon dioxide are two gases involved in the process of photosynthesis. Oxygen and carbon dioxide, like most other kinds of matter, are composed of tiny particles called molecules. Molecules in turn are composed of still smaller particles—atoms. A molecule of carbon *dioxide* is composed of one atom of carbon and two atoms of oxygen. Scientists often use abbreviations to stand for chemical substances. The chemical abbreviation for carbon dioxide is CO_2. The chemical symbol for a molecule of oxygen is O_2. This means a molecule of oxygen gas is composed of two oxygen atoms.

Both carbon dioxide and oxygen molecules have two oxygen atoms in their makeup. Knowing this, many early workers thought that the oxygen molecules released by plants came from the oxygen part of CO_2. Careful measurements *seemed* to verify their conclusion. For every molecule of O_2 released by a plant, a molecule of CO_2 was taken in.

Scientists also knew that water, H_2O, was needed for photosynthesis. It was found that the food materials (sugar and starch) produced as a result of photosynthesis contained carbon, hydrogen, and oxygen. It was thought that the carbon came from carbon dioxide and that the hydrogen and oxygen came from water. Evidence supporting this came from the knowledge that every sugar molecule produced contained two atoms of hydrogen for each one of carbon and oxygen. This ratio was the same as in water—two hydrogen atoms for every oxygen atom.

The picture seemed complete. But as is always true in science, some questioned this apparently logical explanation. With the invention of new measuring instruments, it became possible to test the idea more thoroughly.

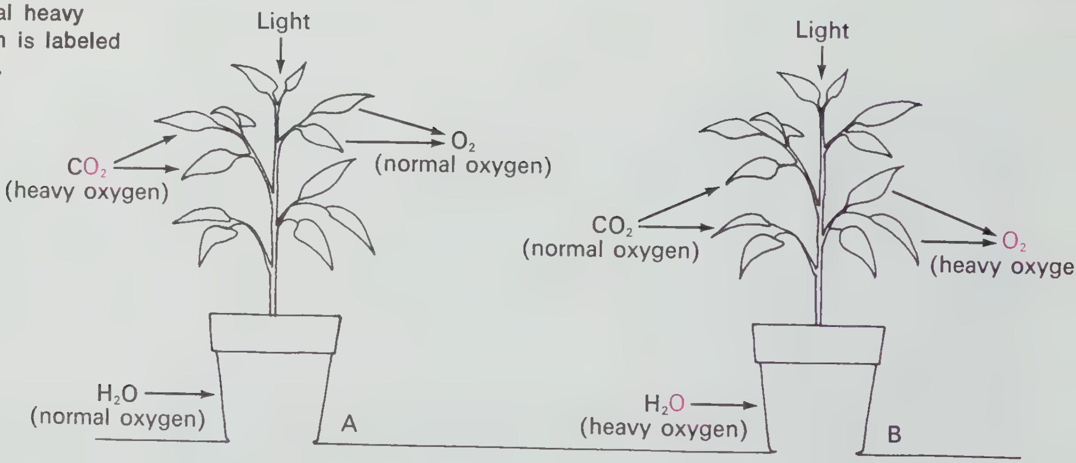
In one important experiment, water and carbon dioxide molecules whose oxygen atoms were heavier than normal oxygen were produced. Using the new equipment to detect these unusual oxygen atoms, scientists set up an experiment to trace their movement through a plant. Figure 2 • 10 shows how the experiment was set up. Study the illustrations and interpret the results.

FOR CLASS DISCUSSION

1. What does Figure 2 • 10A reveal about the source of oxygen released during photosynthesis?
2. Interpret the results of the part of the experiment shown in Figure 2 • 10B.
3. What is the role of water in photosynthesis?

You should now rewrite your equation for photosynthesis and add "water."

Figure 2 • 10. The diagrams show what was allowed to enter the test plant and what was given off. The unusual heavy oxygen is labeled in red.



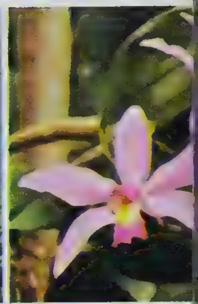
Extending Your Knowledge

The different numbers and types of plants in certain areas of the biosphere are to a degree the result of a difference in the environment that affects photosynthesis. The photographs on pages 48–49 show plant growth in five areas of the biosphere. On page 50 are five graphs showing rainfall and temperature for the five areas. Discuss with your teacher how you might match the graphs of environmental factors with the photographs of the corresponding plant growth.

Different Types of Plant Growth

Figure 2 • 11.

A. Island rain forest. *Right:* orchid, a rain-forest plant.



B. Nebraska grassland. *Right:* prairie clover, a grassland plant.

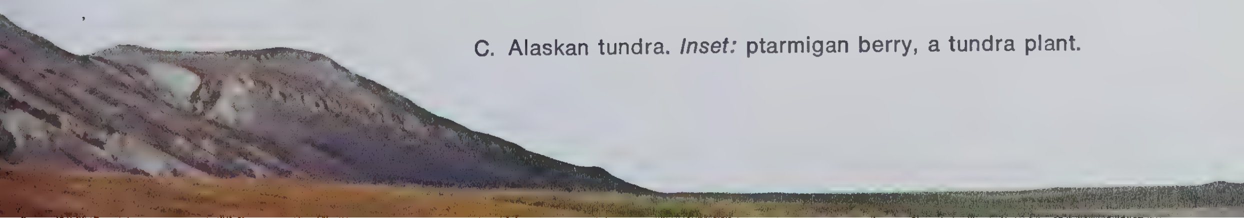
Prickly-pear cactus, a desert plant.

D. New England forest.

Indian pipe, a forest plant.

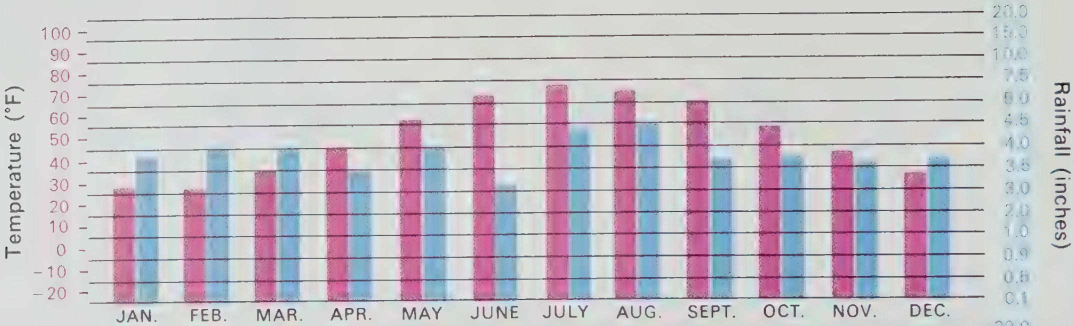
E. Arizona desert.

On the following page are graphs showing the yearly temperature and rainfall for these areas. The numbers on the right side show rainfall in inches; those on the left indicate temperature in degrees F. Try to match the graphs with these scenes of plant growth.



C. Alaskan tundra. *Inset:* ptarmigan berry, a tundra plant.

1



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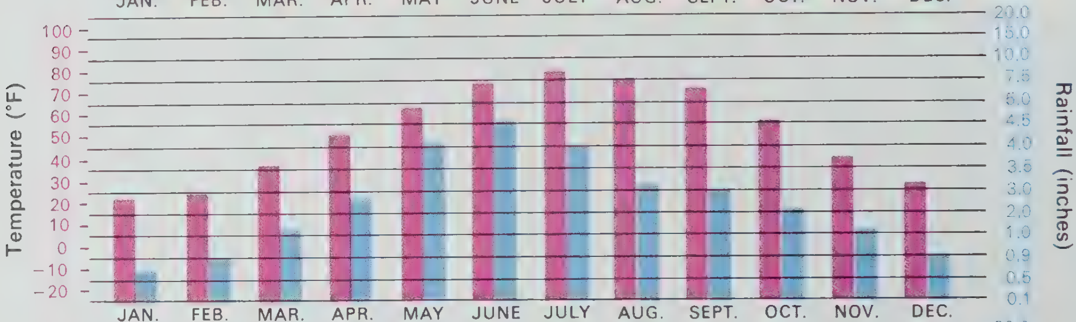

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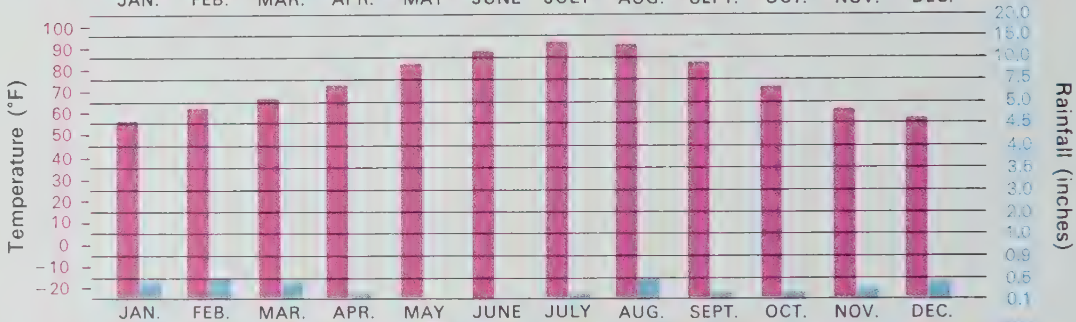

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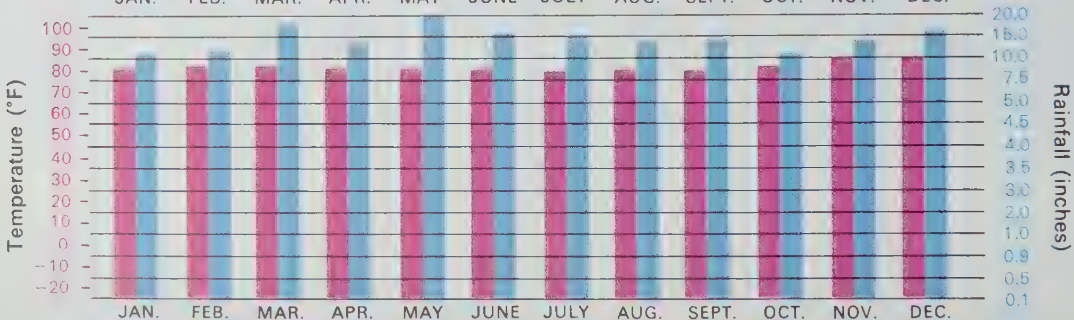

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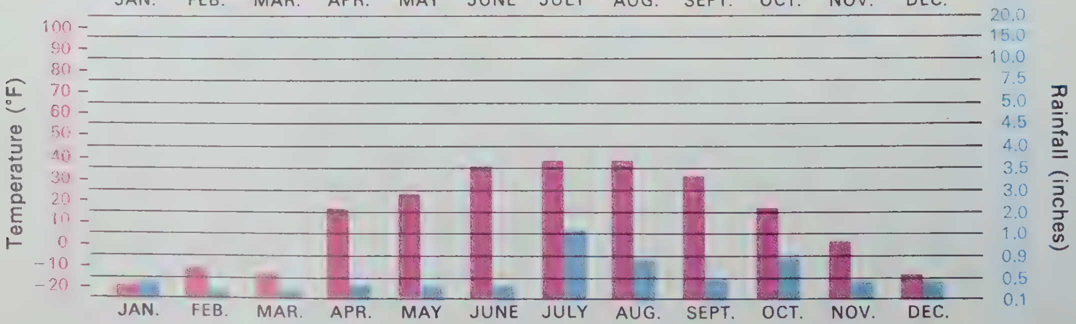


Temperature Rainfall

SECTION THREE

An Interaction Within an Organism

Green plants are called *producers* since they produce and store substances which may become food for other organisms as well as for themselves. Organisms that eat other organisms are called *consumers*. All animals in the biosphere are consumers. This interaction between consumer and producer is one of the basic interactions in the biosphere.

Making Foods Useful

How do consumers obtain the energy stored in the organisms they feed on? What happens to food after it is swallowed? Can food be used as it is? Do animals have special structures to help them convert food to a usable form? In Section Three you will explore these and many other questions.

INVESTIGATION 3.1: Anatomy of a Digestive System

We don't know how our ancestors first learned about digestive systems in animals. It was probably by accident. As hunters cut open their prey, they probably noticed some long tubes and pouches inside the animals. Grazing animals probably had some grass in various states of "decay" in the pouches. Predators may have had pouches containing the remains of their prey. There is no way of telling what primitive people thought of these observations. But in cutting open animals, they were beginning to learn something about animals' *internal anatomy* (inside structure).

Your study of the use of food will begin in much the same way. First you will examine the anatomy of a digestive system. Then you will investigate in more detail how that system works.

A frog's digestive system is easy to observe. Much of what you learn of the frog's anatomy will be true for many other animals, including yourself.

MATERIALS

Frog (preserved)
Dissecting board
Pins
Scissors
Sharp knife or single-edged razor blade
Paper towels
Metric ruler

PROCEDURES

A. Place the frog on the dissecting board and pin the legs down, as shown in Figure 3 • 1.

B. Make *incisions* (cuts) through the skin, as shown in Figure 3 • 1A. Pull the flaps of skin apart and pin down, as in Figure 3 • 1B.

C. Notice the blood vessels under the skin. Observe the abdominal muscle layer, and notice the large vein located in it.

D. Cut through the abdominal muscles just to the left (*your* left—the frog's right) of the vein. Do not let the scissors damage

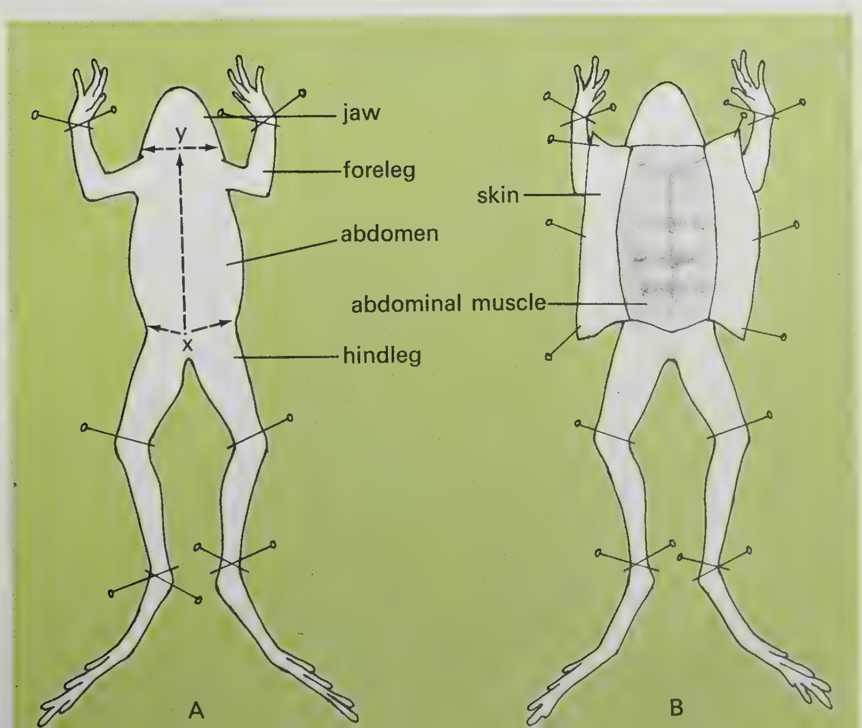


Figure 3 • 1.
A. Begin cutting by lifting the frog's skin at X and inserting the scissors point. Cut from X to Y. Then make the remaining incisions as shown by the arrows.
B. Pin down the two flaps.

the structures lying just under the tissue you are cutting. Extend the cut up toward the jaw. When you get near the forelegs, cut very slowly and carefully. This is the region of the heart and several important blood vessels, which you must be careful not to damage. There is bone between the forelegs that must be cut carefully. Extend the cut up through this bone.

E. Make cuts at right angles to the central incision so that the flaps of muscular tissue can be pulled back and pinned to the dissecting board.

F. Open the mouth of the frog. Observe the *tongue* and the place where it is attached to the lower jaw. The two bumps on the roof of the mouth between the internal openings of the *nostrils* are the *teeth*. At the back of the mouth, find the opening of a tube. This tube, the *esophagus*, leads to the stomach.

G. Identify the *liver*. It is a large, dark structure found under the bone that you cut. The *gall bladder* is a small, round sac

Figure 3 • 2. Some internal organs of a frog.

attached to the middle part of the liver. What color is the gall bladder? Move aside the left part of the liver. The end of the esophagus and the J-shaped *stomach* may be seen. Had your frog eaten shortly before it died? How might you find out? Describe the inside lining of the stomach. At the bottom of the stomach, you should notice the beginning of a small tube, the *small intestine*. Is it straight or coiled? How is it attached to the back of the frog? How long is the small intestine? The *pancreas* is located near the junction of the stomach and the small intestine. It is a small, flat, light-yellow body held in a thin membrane that is attached to both the stomach and the small intestine. You may also see a mass of yellow, fingerlike structures attached to membranes near the back of your frog. These are *fat bodies,* storage organs for fat. Follow the small intestine until it joins a somewhat larger tube near the lower end of the abdomen. This is the *large intestine*. The large intestine leads to the outside of the frog.

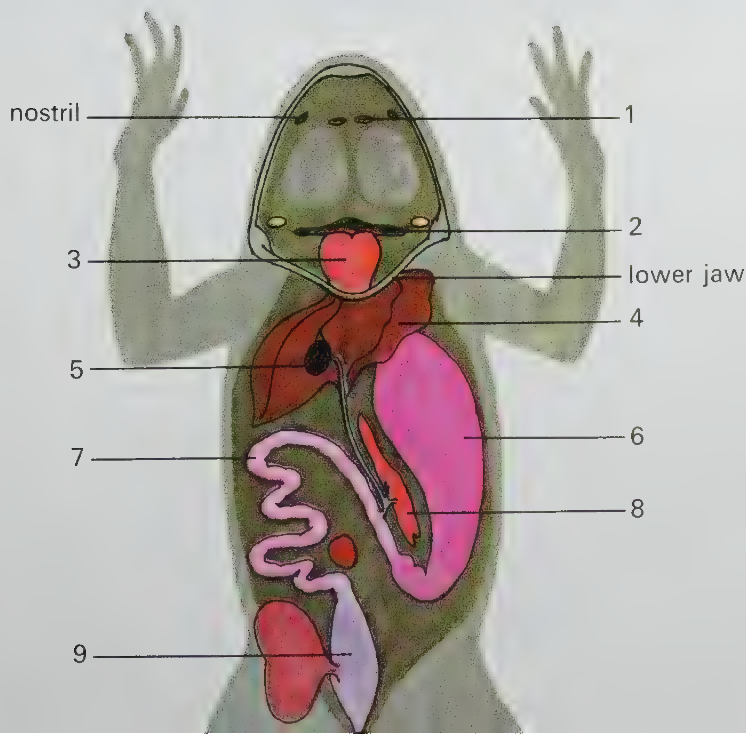


Figure 3 • 3.
The digestive system of a frog.

H. Carefully remove the frog from the dissecting board. Pin the body-wall flaps together. Wrap some wet paper toweling around the frog and return it to the place indicated by your teacher. You may need the frog again.

ANALYSIS

1. In your notebook, record answers to the questions asked in Procedure G.
2. In your notebook, name the numbered parts of the frog's digestive system, shown in Figure 3 • 3.
3. The stomach is larger than the tube leading to it and the tube leading from it. What does this size difference suggest about one function of the stomach?
4. What do you think happens to the food in the stomach and the intestines?

During the next series of investigations, you will study plants to help you answer questions like Question 4.

Growth of Bean Plants

A class of students was investigating how plants grow. Each day the students took several growing plants, dried them, and recorded the dry weights of the *embryos* and cotyledons (the two seed halves).

The students' data are plotted on the graph—Figure 3 • 5.

Suggest a hypothesis to explain why the embryo gained weight as the cotyledon lost weight.

Figure 3 • 4. Stages in the growth of a bean plant.

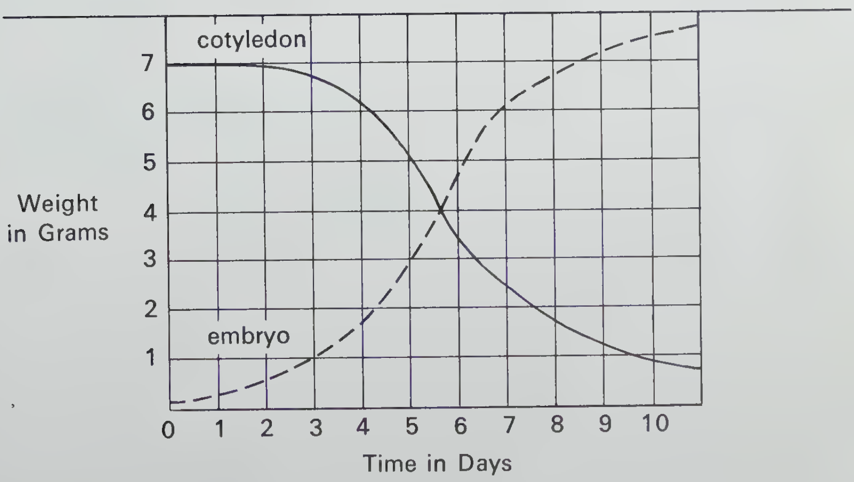


Figure 3 • 5.

INVESTIGATION 3.2: Location of Food in Germinating Seeds

There are sugar tests other than the one using Benedict's solution, which you used in Section Two. The tetrazolium test is good for showing the location of sugar in seeds. An area of a seed in which sugar is present will turn either pink or red in the presence of tetrazolium.

MATERIALS

Soaked red kidney bean seeds, 4
Tetrazolium solution
IKI solution
Small petri dishes or other flat dishes, 2
Single-edged razor blade

PROCEDURES

A. Carefully separate the halves of each of the bean seeds with a razor blade. In one half of each seed you will see a new young plant—an *embryo*. Be sure the embryo is all on one half of a seed. *Remove any seed coat that may stick to the cotyledon.* Discard the half without an embryo.
B. Pour a thin film of tetrazolium solution into a flat dish. Place two seed halves—each containing an embryo—in the dish. Be sure the flat side of the cotyledon is down (see Figure 3 • 6B).
C. Make observations at ten-minute intervals during the class period. Record your observations.
D. Put each of the two remaining seed halves containing embryos in a dish. Place them so that the flat side of the cotyledon is facing up. Put a drop of IKI solution on the side of the cotyledon with the embryo. Record your observations.
E. In your notebook, sketch the half of the bean seed containing the embryo. Label areas containing sugar and starch.

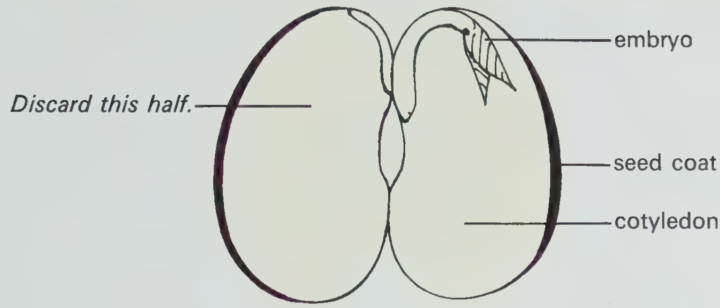


Figure 3 • 6A. Parts of a bean seed.

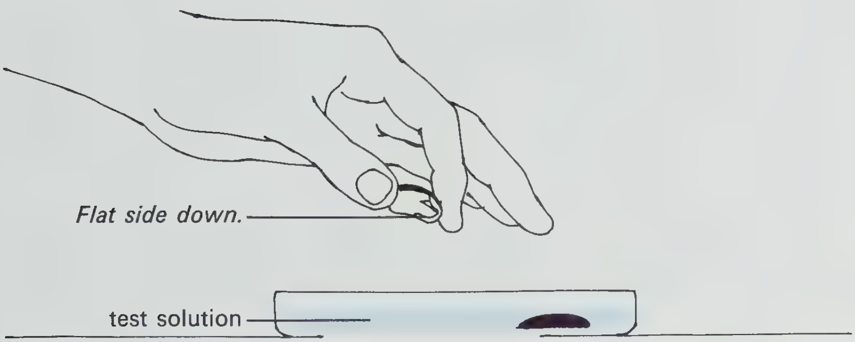


Figure 3 • 6B. Carrying out Procedure B.

ANALYSIS

1. What part of the seed contains sugar?
2. What part of the seed contains starch?
3. What kind of food that could be used for growth is in the embryo?
4. In what form is food apparently stored in the cotyledons?

INVESTIGATION 3.3: A Cell Model

Now you should know where starch is stored in a bean seed. But how does the food get from a cotyledon into the cells of a growing embryo?

Between the outer edges of the cotyledon and the embryo there are thousands of cells, and the embryo itself has many cells.

The cells of the embryo are too small for you to work with in the laboratory. You can, however, use a substitute for a cell to help answer the question.

A dialysis membrane and a cell membrane affect the movement of starch and sugar in similar ways. A dialysis membrane filled with liquid may be used as a giant model of a cell (see Figure 3 • 7). How would you use a dialysis membrane to find out if starch can pass through a cell membrane?

Design and carry out an investigation to answer this question.

After finding the answer, modify your experiment to answer the question: Can sugar pass through the membrane?

Figure 3 • 7. Dialysis membrane filled with liquid.

INVESTIGATION 3.4: A Problem

MATERIALS

White 3 x 5 cards
IKI solution
Red kidney bean seeds soaking in water for 24 hours

PROCEDURES

A. Dip one end of a white 3 × 5 card into a beaker of IKI solution.
B. Obtain several ml of water from a beaker in which bean seeds have been soaking. Place several drops on the IKI-stained part of the card.
C. Record your observations.

ANALYSIS

1. How do you explain the change?
2. From where do you think the substance came that caused the change? Do not be satisfied with just one idea.

ON YOUR OWN: A New Substance?

Design and carry out a similar investigation that will allow you to answer the following questions:

1. Did water or some substance in the water cause the change that occurred in Investigation 3.4?
2. If the change was brought about by some substance in the water, that substance must have come from the beans. Prepare a list of all the parts of a bean that could be sources of that substance. Which item on your list is most likely to be the source?

Biological Converters

There seems to be *something* produced by soaked seeds that is capable of bleaching the dark color on the IKI-treated cards. For now, you might call that something a biological converter. The next investigation may provide a clue to the function of biological converters.

INVESTIGATION 3.5: Soaked Beans and Starch

MATERIALS

Dialysis membrane (about 20 cm long), 2 pieces
Starch suspension
IKI solution
Benedict's solution
Water in which red kidney bean seeds have been soaked
Test tubes, 2
Medicine droppers, 2
String
Water bath
Test-tube holder
Rubber bands, 2

PROCEDURES (Day 1)

A. Copy Figure 3 • 8 in your notebook. Test 5 ml of starch suspension for sugar, using 5 ml of Benedict's solution. Record results in your notebook.
B. Securely tie one end of the dialysis membrane. Prepare a mixture containing 5 ml of starch suspension and 5 ml of bean water. Carefully pour the mixture into the dialysis membrane. Rinse the outside of the membrane with clean water.
C. Place the tubing in a test tube—see Figure 3 • 9. Support the tubing in an upright position by folding the untied end over

Test Tube	*Test*	*Location*	*Day 1*	*Day 2*
1	Sugar Test	Inside Membrane		
		Outside Membrane		
	Starch Test	Inside Membrane		
		Outside Membrane		
2	Sugar Test	Inside Membrane		
		Outside Membrane		
	Starch Test	Inside Membrane		
		Outside Membrane		

Figure 3 • 8.

the edge of the test tube. Fasten with a rubber band. Pour water into the test tube until it is about full. Label the tube No. 1.

D. Label a second tube No. 2. Repeat Procedures B and C, but substitute 5 ml of tap water for 5 ml of bean water.

E. Near the end of the class period, use a medicine dropper to remove about 3 ml of the mixture from inside each membrane. Test each sample for the presence of sugar and starch, and record your results in the chart. Using a clean medicine dropper, remove about 3 ml of water from each test tube (outside the membrane) and test for starch and sugar. Record results on the chart in your notebook. Leave the dialysis membranes in the test tubes until the next class period.

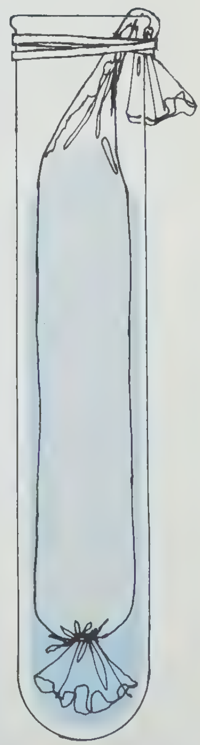


Figure 3 • 9. Setup for Procedures B and C.

PROCEDURE (Day 2)

At the beginning of the period, repeat Procedure E. Record results on your chart.

ANALYSIS

1. What effect did the bean water seem to have on starch?
2. In what form do you think food in a growing plant is stored? What process must occur before stored food is used by a plant for growth?
3. What is the purpose of having tube No. 2?

ON YOUR OWN: Saliva and Starch

Saliva is a watery fluid produced by glands that open into your mouth (see Figure 3 • 11). Design and carry out an investigation to see if saliva will react in any way with starch. You might wish to use the same techniques you used in Investigation 3.5. If so, copy Figure 3 • 10 in your notebook. Ask your teacher to supply the materials you will need.

Figure 3 • 10.

Test Tube	*Test*	*Location*	*Day 1*	*Day 2*
1	Sugar Test	Inside Membrane		
		Outside Membrane		
	Starch Test	Inside Membrane		
		Outside Membrane		
2	Sugar Test	Inside Membrane		
		Outside Membrane		
	Starch Test	Inside Membrane		
		Outside Membrane		

Figure 3 • 11. Location of the glands that produce saliva.

ANALYSIS

1. What effect did saliva have on starch?
2. Why do you think it is important for food to be broken down into small particles?
3. Did you provide a control in this investigation? If so, explain what variable was controlled.

Enzymes

There is something in bean water and something in saliva that can change starch to sugar. It has been known for centuries that something in molds and yeasts can also change one substance to another. People have used this knowledge in making bread, cheeses, and wines. It wasn't until the nineteenth century that scientists learned what that something was.

One line of investigation followed by the great scientist Louis Pasteur involved the production of wine. He found that the alcohol in wine came from the fermentation of sugar from crushed grapes. That is, sugar is broken down to alcohol and carbon dioxide. Living yeast cells seemed to be necessary for fermentation to occur. How did these cells do the job?

In 1897 a German, Eduard Buchner, ground yeast cells to a pulp with a mortar and pestle. When the solid matter was re-

Figure 3 • 12.
In the process of making wine, the temperature of the fermenting grapes is checked several times.

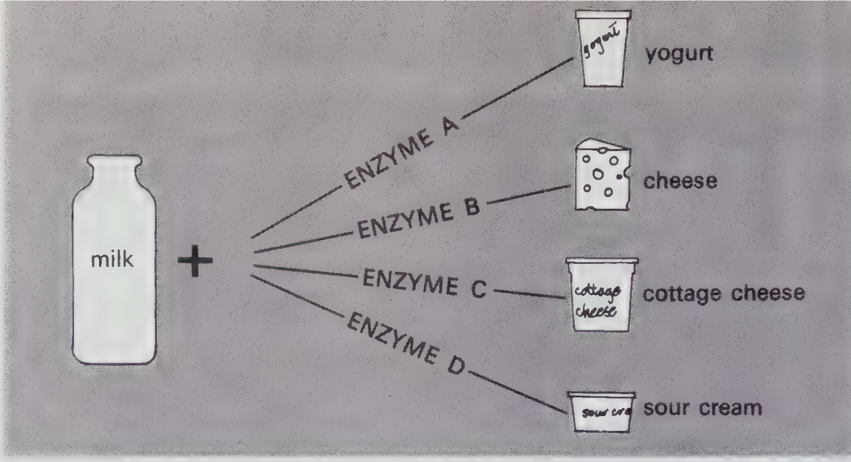


Figure 3 • 13. Some applications of enzymes. Different enzymes cause different reactions.

moved and the remaining liquid was added to grape juice, *fermentation* occurred. Buchner was the first to cause fermentation to occur when living cells were not present. This proved to be the beginning of an important field of research. We know now that the liquid Buchner used contained substances called *enzymes* (Greek: "in yeast").

An enzyme found in human saliva can regulate the chemical change of starch into sugar. The action of saliva on starch is the beginning of the process of *digestion*—the breaking down of food into tiny particles that can pass through cell membranes.

NOTE: *Enzymes have more than just a digestive function. In general, all of the thousands of chemical reactions going on in cells are regulated by different enzymes. The process of digestion illustrates only one kind of enzyme function.*

INVESTIGATION 3.6: Comparing Two Reactions

MATERIALS

Starch
Benedict's solution
150-ml beakers, 2
Heat source

PROCEDURES

A. Label one beaker A and the other B. Add 50 ml of water to each beaker.
B. Add a pinch of starch and 5 ml of saliva to Beaker A. Allow

the mixture to stand at room temperature for 15 minutes.

C. Add 5 ml of Benedict's solution to Beaker B. Bring to a boil. *After* the water is boiling, add a pinch of starch and continue boiling for 15 minutes. Observe and record the results.

D. Test Beaker A for sugar. Record the results.

ANALYSIS

1. Compare the results for the two tests.
2. How does this investigation illustrate the importance of enzymes to reactions going on in living things?

ON YOUR OWN: Temperature and Starch Digestion

You have seen why digestion is necessary and why enzymes are important. You may think this has little to do with the interactions between organisms and the environment, but anything that can influence digestion can influence the well-being of an organism. And internal processes can often be affected by outside interactions. Here you will investigate the problem of environmental temperature and digestion.

MATERIALS

- Graduated cylinder
- Starch-water mixture
- IKI solution
- Test tubes, 6
- 600-ml beakers for water baths, 3
- Spot plate or microscope slides
- Thermometer
- Ice
- Heat source

PROCEDURES

A. Collect 2 ml of saliva in each of three test tubes. Label them 1, 2, and 3. Place Tube 1 in a water bath containing ice water or cold tap water. Place Tube 2 in a water bath at room tem-

perature (22°–25°C). Place Tube 3 in a warm-water bath (35°–37°C).

B. Pour 10 ml of the starch-water mixture into each of three additional test tubes. Place one test tube in each water bath. Leave all six test tubes in the water baths for five minutes. While waiting, read through the rest of the procedures and copy Figure 3 • 14 in your notebook.

C. After five minutes pour each tube of starch solution into the tube of saliva in the same water bath and mix thoroughly. Return each numbered tube to the same water bath from which it was taken.

Figure 3 • 14.

Test-Tube Number	*Water-Bath Temperature*	*Time for Digestion to Occur*
1	Ice Water (0°-5°C)	
2	Room Temp. (22°-25°C)	
3	Warm Water (35°-37°C)	

D. At one-minute intervals remove a small sample of the starch-saliva mixture from each test tube and, on a spot plate or microscope slide, test for starch with a drop of IKI solution. A positive starch test indicates that "digestion" is *not* complete. It is complete when the starch test is negative. Continue testing each tube at one-minute intervals until you no longer obtain a positive starch test. Record the time necessary for "digestion" to occur.

ANALYSIS

1. In which tube was "digestion" most rapid?
2. In which tube was "digestion" slowest?
3. Describe the effect that an increase in temperature appears to have on the rate of starch digestion.
4. What effect would lowering the temperature probably have on the organisms in your grass-water mixture?

Other Foods

You have investigated the digestion of starch by an enzyme found in saliva. But you eat many other things besides starch. (In fact, you could not survive very long if you ate nothing but starch.) The food you eat is grouped into three large classes—carbohydrates, proteins, and fats.

The sugar and starch that you have studied are carbohydrates. Beans, bread, and potatoes are examples of foods that are high in carbohydrates.

Meat, milk, the whites of eggs, and some kinds of plant material, including beans, are high in proteins.

Lard, oils, and fats constitute the third class of foods, called fats.

The bodies of both plants and animals are built of varying amounts of all three classes of foods. Most plants are largely composed of carbohydrates and water, with smaller amounts of protein and fat. The animal body is largely protein and water. Nearly every part of your body has protein associated with it. Some parts that contain especially large amounts of protein are muscle, blood, hair, and skin. Enzymes are also made of protein.

The digestion of starch begins in the mouth and continues for a short time in the stomach. Then other enzymes act, and other foods are digested. The digestion of protein begins in the stomach.

INVESTIGATION 3.7: Digestion of Protein

Digestion in the stomach is aided by the secretion of *gastric juice*. Gastric juice contains several substances, one of them an enzyme called pepsin.

MATERIALS

Baby-food jars or beakers, 3
Pepsin
Dilute hydrochloric acid
Forceps
Hot-water bath
Triangular file
6-mm outside diameter glass tube
Fresh egg (source of protein)

PROCEDURES

A. Crack open an egg. Separate the yellow yolk from the white material. Suck the egg white up into the glass tube. Make sure the tube is almost full of egg white.

B. Place the tube in boiling water until the egg white is cooked (about 20–30 seconds).

C. Using forceps, remove the glass tube and allow it to cool. Using a triangular file, notch the tube at 3-cm intervals. Holding the tube with a towel, turn the cut side *away* from you and break it at each notch. These tubes containing boiled egg white are called Mett's tubes.

D. Label the jars 1, 2, and 3. To Jar 1 add 50 ml of dilute hydrochloric acid solution. To Jar 2 add 50 ml of pepsin solution. To Jar 3 add 50 ml of pepsin-HC1 mixture.

CAUTION: *Measure the amounts carefully. NEVER return any excess to the solution bottle. Always discard excess amounts. This will avoid contamination of the solutions.*

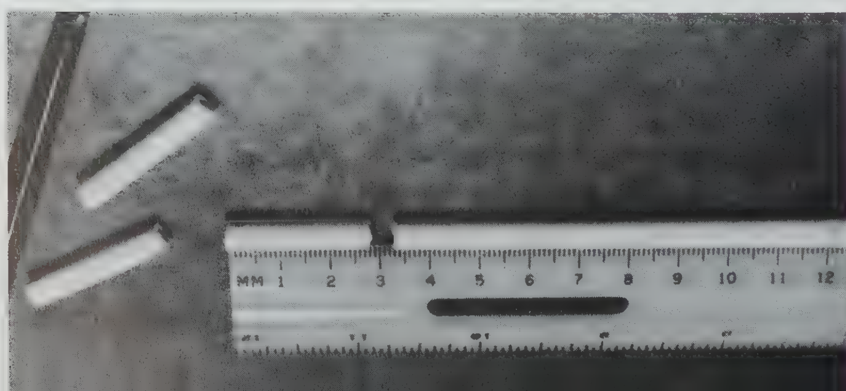


Figure 3 • 15. Mett's tubes prepared for use in Procedure E.

E. Place a 3-cm tube of egg white in each jar. Observe and measure the clear areas at the ends of the glass tubes daily for three days.

ANALYSIS

1. In which tube did the most "digestion" occur?
2. What conditions do you think are necessary for protein to be digested in the stomach?
3. What is the function of Setups 1 and 2 in this investigation?

The Role of pH in Digestion

The action of enzymes is affected by heat. The activity of enzymes also depends upon the pH of the surrounding substance. The term "pH" is used to describe whether a substance is an *acid* or a *base*. Vinegar and lemon juice are acids, and baking soda and household ammonia are bases. Pure water is neither an acid nor a base and is called *neutral*. Some acids and bases are stronger than others. In order to discuss the strengths of acids and bases, scientists use a pH scale (Figure 3 • 16).

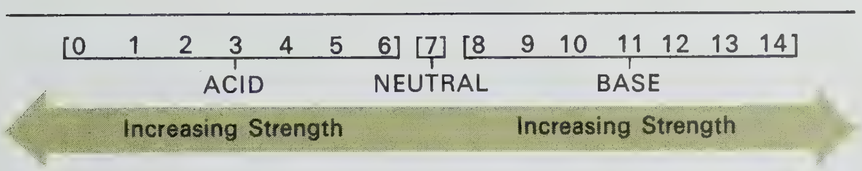


Figure 3 • 16. The pH scale.

A substance that is neutral, such as pure water, has a pH of 7. A number higher than 7 indicates a base; a number lower than 7 indicates an acid. During the next investigation you will study the effect of pH on the action of pepsin, a digestive enzyme found in the stomach.

Since the pH of the environment is important, the addition of either vinegar or baking soda to your grass-water mixture may have a considerable effect. You might wish to investigate this.

ON YOUR OWN: Effect of pH

In the last investigation you saw the effect that acid has on the activity of the protein-digesting enzyme pepsin.

What would happen if you changed the amount of acid (pH)? What would happen if you used a base instead of an acid?

MATERIALS

150-ml beakers or jars, 7
Stock solutions
Hydrochloric acid–pepsin mixture
Ammonium hydroxide–pepsin mixture
Mett's tubes, with egg white, 7
Forceps
Metric ruler

PROCEDURES

A. Label the beakers 1–7. The stock solutions have already been prepared and numbered for identification. Add 50 ml of each numbered stock solution to the glass container with the corresponding number.
B. Add a Mett's tube (3 cm long) to each beaker.
C. In your notebook, copy Figure 3 • 17.
D. Daily for three days measure the clear areas in the ends of each tube that indicate "digestion" has taken place. Find the

Figure 3 • 17.

Stock Solution	*Ml of HCl in 50 Ml of Stock Solution*	*Acid or Base*	*Ml of Pepsin Solution*	*Results: Mm Clear Zone*		
				Day 1	Day 2	Day 3
1	2.0	Acid	50			
2	1.0	Acid	50			
3	0.5	Acid	50			
4	0.25	Acid	50			
5	0.12	Acid	50			
6	0.06	Acid	50			
7	1.0 ml of NH_4OH in 50 ml of stock solution	Base	50			

total length of clear zones in both ends of each tube. Record the measurements in your chart. Copy Figure 3 • 18 in your notebook; prepare a bar graph of the results seen on Day 3.

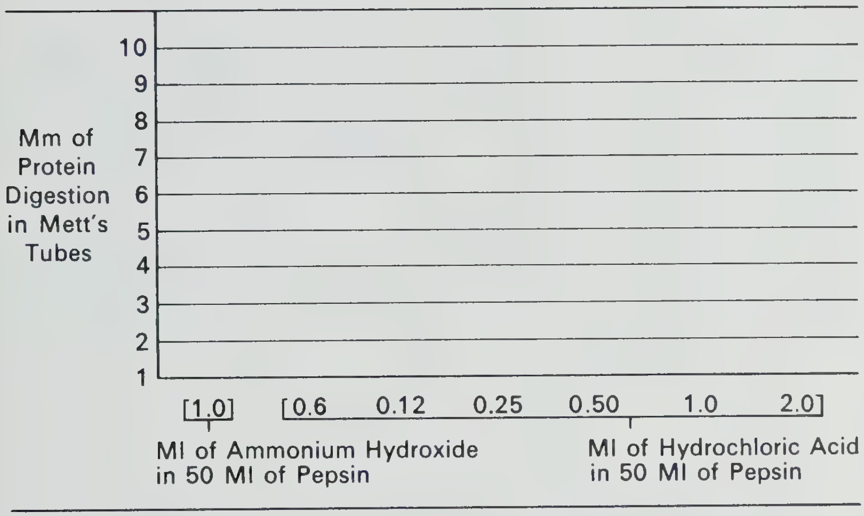


Figure 3 • 18.

ANALYSIS

1. In which tube was the "digestion" greatest?
2. Discuss the importance of pH in digestion by pepsin.
3. Why do you think starch digestion by saliva might stop after the food-saliva mixture reaches the stomach?

INVESTIGATION 3.8: Digestion in the Small Intestine

Some stages of protein digestion occur in the stomach. But the digestion is not completed there. Most of it occurs in the small intestine.

Remember that pH is important in efficient operation of enzymes. Saliva is almost neutral. Material in the stomach is acidic. This means that an enzyme present in the mouth might not be active after it has been in the stomach for some time. Material in the intestine is basic: its pH is greater than 7. How might this affect an enzyme from the stomach?

In the small intestine, substances such as enzymes that aid in digestion come from the liver, pancreas, and special cells found in the lining of the small intestine itself. These substances finish the process of digestion.

MATERIALS

Mett's tubes containing lard, 3
Mett's tubes containing egg white, 3
Pancreatin solution
Pepsin solution
Test tubes, 6
Triangular file
Metric ruler

PROCEDURES

A. Copy Figure 3 • 19 in your notebook.

Figure 3 • 19.

Test Tube	*Contents of Tube*	*Observations*	
		Day 1	*Day 2*
1	Protein (egg white) + Pepsin		
2	Fat (lard) + Pepsin		
3	Protein (egg white) + Pancreatin		
4	Fat (lard) + Pancreatin		
5	Protein (egg white) + Water		
6	Fat (lard) + Water		

B. Label six test tubes 1–6.

C. Prepare three 3-cm sections of Mett's tubes containing egg white.

D. Prepare three 3-cm sections of Mett's tubes containing lard.

E. Add materials to each of the six test tubes as follows:

Tube No. 1: 20 ml of pepsin solution and 1 Mett's tube (with egg white)

Tube No. 2: 20 ml of pepsin solution and 1 Mett's tube (with lard)

Tube No. 3: 20 ml of Pancreatin solution and 1 Mett's tube (with egg white)

Tube No. 4: 20 ml of Pancreatin solution and 1 Mett's tube (with lard)

Tube No. 5: 20 ml of tap water and 1 Mett's tube (with egg white)

Tube No. 6: 20 ml of tap water and 1 Mett's tube (with lard)

F. Observe the contents of each test tube for two days.

G. If partial "digestion" of the material in each Mett's tube occurs, write a + sign under observations for Days 1 and 2. If total (or nearly total) "digestion" occurs, write two + signs. If *no* "digestion" occurs, write a — sign.

ANALYSIS

Basing your work on this and previous investigations, list and describe in detail all the factors you think influence the process of digestion.

How Cells Obtain Food

Once the food you eat is digested, how does it get into the cells in your body? Each cell is surrounded by a very thin membrane. Somehow food material must pass through that membrane. Once inside the cell, part of the food is used. Waste materials must then pass out through the membrane and leave the cell.

No one knows exactly how materials pass through cell membranes. Biologists have been trying to find out ever since cells were discovered. But some things are known about food materials themselves. Food is made up of small particles called molecules. Molecules vary in size and shape, just as cells do. The size and shape of a molecule depend upon the atoms making up the molecule. For the moment, think of an atom as if it were a marble. A single marble can represent one atom. If two or more marbles are fastened together, the combination can represent a molecule. Some molecules are so complex that it would take thousands of marbles fastened together to represent them.

We still have not answered the question of how molecules move into cells. Part of the answer lies in the behavior of molecules. They are thought to be in constant motion. In a solid material like wood, they are not free to move very great distances. In a liquid, they have greater freedom. Molecules of a gas, such as oxygen or carbon dioxide, have still greater freedom to move and, indeed, may move great distances.

You can visualize this point rather simply. Suppose that a skunk enters your classroom unnoticed and discharges its odor at the front of the room. How long do you think it would take for the students at the back of the room to detect the odor? Probably only a few seconds. Like all matter, the fluid discharged by the skunk is made up of molecules. These molecules—let's call them skunk-odor molecules—move about at random and collide with each other. They also collide with molecules of gases normally found in air. Aided by air currents, the molecules will move throughout the room (and probably down the hall into many other rooms). The movement of molecules from where there are many (in the front of the room) to where there are few (in the

back of the room) is called *diffusion* (recall Investigations 3.3 and 3.5). This movement continues as molecules bounce around in all directions. Soon they will be spread evenly throughout the area. At that time, about the same number of molecules will be bouncing toward the front as toward the back, and so a state of balance will exist.

Now suppose that the room is partitioned by a giant window screen stretched from floor to ceiling. If the "skunk-odor molecules" can go through the screen, diffusion will take place until a balance is reached—just as if the screen did not exist. And this is part of the answer to the question of how cells take in food. Small food molecules outside a cell diffuse toward a place where there are fewer food molecules—toward the inside of the cell.

Wastes produced in the cell act in the same way. They leave the cell by diffusing out through the membrane.

Diffusion of molecules through membranes takes place in all living cells. But a cell membrane is a complex structure, and simple movement of molecules does not tell the whole story. The cell membrane is able to allow some kinds of molecules, those of simple sugar, for example, to pass through and reject others, like molecules of starch. Why this is true is not fully understood, but size is part of the answer. Since cell membranes are so thin as to be invisible under the most powerful light microscope, it is not possible to watch what takes place. We can say, however, that as a result of digestion, foods are changed into a form that can pass through cell membranes.

Figure 3 • 20. A cell membrane revealed by an electron microscope. The arrow points to the membrane.

Human Digestive System

In multicellular animals the process of digestion takes place outside the cells that eventually use the products of digestion.

The sea anemone is a multicellular animal that fastens itself to rocks in shallow-water areas along the seacoast. As shown in Figure 3 • 21, its digestive system is like a sack. It has but one opening, through which food and water pass. This opening also serves for the elimination of wastes.

The human digestive tube is obviously more complex than that of the sea anemone. For example, it has two openings, one for the entrance of food and water and one for the exit of wastes. The essential function in both organisms is the same—to break large food molecules into small molecules that can pass through cell membranes.

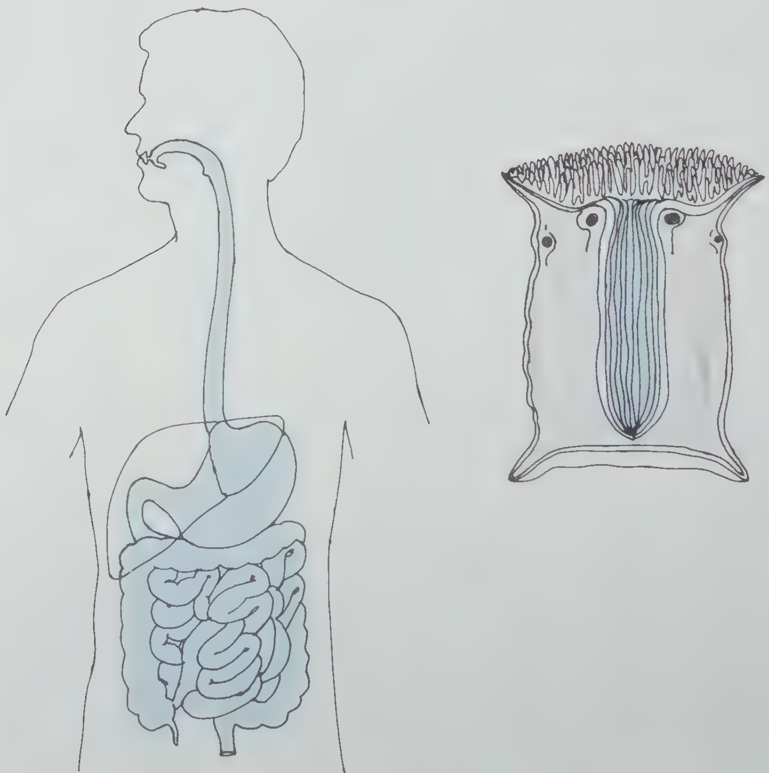


Figure 3 • 21. Comparison of sea-anemone and human digestive systems.

Major parts of the human digestive tube include the mouth, esophagus, stomach, small intestine, large intestine, and rectum (Figure 3 • 23). Digestive fluids are secreted into the digestive tube by other organs—liver, pancreas, gall bladder—and by cells that line the small intestine.

Prior to the 1800's little was known about the function of these various parts of the digestive system. Then in 1822 a young man was wounded in the stomach by a gunshot. Instead of healing normally, the stomach healed around an opening to the outside. The young man, Alexis St. Martin, and his doctor, Dr. William Beaumont, became famous. The doctor was able to directly observe gastric digestion through the opening. This opening made possible a technique so successful that scientists today make surgical openings in the stomachs of experimental animals to observe

Figure 3 • 22A. Dr. William Beaumont pumping a sample of stomach contents from Alexis St. Martin.

Figure 3 • 22B. A steer with a plastic-covered window in its stomach. Dr. Beaumont's success has prompted the use of artificial windows (*as illustrated*) to study digestion.

gastric digestion. Such openings also make it possible to easily study the temperature and acidity of the stomach.

We now know that digestion is aided by waves of muscular contraction that move along the digestive tract. This process of contraction (called *peristalsis*) helps to mix the food mass with enzymes, thus hastening digestion. Peristalsis also moves the food mass through the digestive tube.

When digestion in the stomach has progressed to a certain point, a valve between the stomach and the small intestine opens. Then the food mass moves into the small intestine. What causes the valve to open at the right time? Apparently this is controlled by acid-sensing cells in the stomach wall near the valve. When you eat a meal, it takes time for acid and enzymes to be produced by your stomach. These substances mix with food to start the breakdown of protein. By the time the food has become acidic enough for the valve to open, digestion can be completed in the small intestine. This is one example of an interaction within an organism that maintains efficient working relationships among parts of the body. There are many others.

The liver and pancreas are important in the digestion of food. The digestive juices from both enter the small intestine through a small duct (tube) connected to the upper end of the small intestine. Digestion in the small intestine is also aided by digestive juices from the cells lining its walls. Digestion continues throughout the length of the small intestine, where there are millions of small, fingerlike projections called *villi* (Latin: "shaggy hair"). The villi contain blood and lymph vessels which absorb the products of digestion. The villi greatly increase surface area in the small intestine (Figure 3 • 23).

Usable digested material is absorbed through the villi. Unusable material is moved by peristaltic contractions out of the small intestine into the large intestine. Very little food material is absorbed in the large intestine. There is a rich supply of blood vessels to the large intestine, however, and they absorb most of the water from the intestinal contents. The resulting dehydrated mass remains in the large intestine until it can be voided as waste.

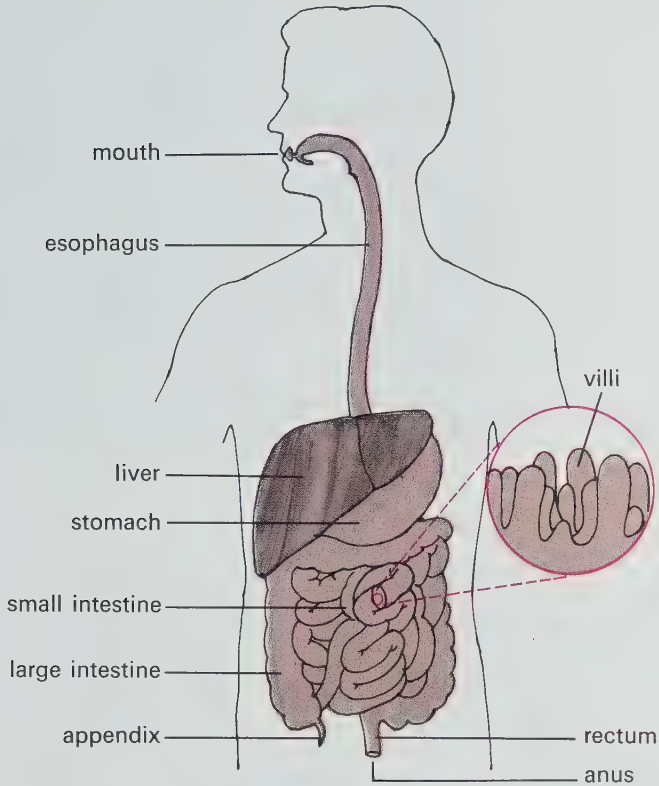


Figure 3 • 23. Human digestive system. Note the enlarged section of small intestine, illustrating villi.

Attached to the large intestine there is a small sac called the appendix. In some animals, such as the rabbit, the appendix has a large population of bacteria that can digest the woody parts of the plants that the animals eat. In humans the appendix has little or no function.

During the process of digestion, food is changed into small molecules that can diffuse through cell membranes. Once inside cells, food molecules provide energy and raw materials for growth.

There is an important problem we have not considered yet. In larger animals most cells are located far from the digestive tract. How are molecules of digested food in the intestines of large mammals (humans, giraffes, bears) transported to cells in their feet or brains, for example? In Section Four, you will be asked to seek an answer to that question.

Chameleon and insect

Feeding: An Interaction

Figure 3 • 24. There are almost as many different ways of feeding as there are different kinds of organisms. Discuss how the structure and the behavior of each of these organisms help it obtain food.

Elephant and vegetation

Snake and fish —

Clam and starfish

Fly and Venus's-flytrap

Moth and flower

Lynx and rabbit

Extending Your Knowledge

Enzymes are large protein molecules produced by cells. As stated previously, enzymes regulate the chemical reactions that take place in the cells of all plants and animals. Some enzymes cannot act alone in cells. They need to be "triggered," or activated, by the presence of an additional substance. Many of the "triggering" substances are vitamins.

Humans cannot directly manufacture any vitamin (except vitamin D) in sufficient quantities to sustain life. Most other animals can manufacture some vitamins, and plants can produce all the different kinds of vitamins they need.

Where do humans obtain the vitamins necessary for life?

Why must green plants be able to manufacture all the vitamins that they need for life?

SECTION FOUR

Transport Problems

Transport in Animals

Suppose you have to give a report on how a nuclear submarine works, without using reference books. Or suppose that you are a mechanic who must keep the submarine in top working condition. You are permitted to study only the outside of the submarine. You can watch what goes into it and what comes out, and you can listen to the sounds coming from it. But under no circumstances are you to go *inside* the boat. After listening to your complaints that you need to know more, your employers might let you look inside a "distant relative" of the submarine—a discarded tugboat. If there are similarities between the tugboat and the nuclear submarine, your knowledge of the tugboat might help you understand the submarine.

Hundreds of years ago scientists and physicians were in a similar position when they tried to describe the internal structure of the human body. They wanted to know more about the living body and how it worked, but they could rarely look inside one. Sometimes they managed to dissect and observe the internal structure in dead bodies. But this was illegal in many countries. Besides, after death the body's normal functions stop.

Because of these limitations, scientists learned as much as they could from the *external* (outside) appearance of the body. They also looked inside the bodies of other animals. But sometimes these animals were as different from humans as the tugboat is from the nuclear submarine. From their observations scientists tried to understand the human body and keep it in good working order.

Of course, the situation is considerably different now. Much more is known about what is in the body and how it works. Surgeons can even replace some parts that do not work properly. You have much less education than surgeons have, but you probably know more about the human transport system (circulatory system) than even the greatest scientists knew 500 years ago. But even with that knowledge you may experience some of the difficulties they did as you perform Investigation 4.1.

INVESTIGATION 4.1: Pulse Rate

MATERIALS

Watch with sweep second hand

PROCEDURES

A. One student is the subject. Another student is the observer. The observer presses two or three fingertips of his right hand on the inside wristbone of the subject's left hand, on the thumb side of the wrist.

Figure 4 • 1.
Finding the pulse.

B. The observer counts the number of pulsebeats in 15 seconds and multiplies this number by 4 (4×15 seconds $= 60$ seconds). The number that results is the number of pulsebeats per minute—the usual measure used to report pulse rate.

C. The subject puts his head down on his desk and remains perfectly still for five minutes. Then the observer takes the subject's pulse and records it in a chart in his notebook, as in Figure 4 • 2, under the column labeled "Resting."

D. The observer has the subject stand up and move normally for two minutes. Then he takes the subject's pulse and enters the results in the column labeled "Normal Activity."

Figure 4 • 2.

Student's Name	Resting	Normal Activity	After Exercise

E. Now the observer has the subject exercise vigorously for two minutes. Immediately after exercise, he takes the subject's pulse and records the results in the column labeled "After Exercise."

F. Procedures A through E are repeated, with each member of the team acting as a subject and as an observer.

ANALYSIS

1. What is the effect of exercise on the pulse rate?
2. Why do you think such an effect is important?

FOR FURTHER ACTIVITY

1. Is there a measurable difference in the resting pulse rates of boys and of girls?
2. Does height or weight appear to affect pulse rate?

Anatomy of a Circulatory System

In the next investigation try to trace the path of blood after it leaves the heart of a frog. The illustration will help you follow the vessels until they enter various organs and tissues. The blood is carried (transported) in three kinds of vessels:

1. *Arteries,* which carry blood away from the heart.
2. *Capillaries,* which form networks near the cells. (They are so small that you cannot see them without a microscope.)
3. *Veins,* which carry blood back to the heart.

Arteries branch repeatedly until they become the capillaries, and capillaries unite to form the veins.

INVESTIGATION 4.2: Circulatory System of a Frog

MATERIALS

Frog (preserved)
Dissecting board
Pins
Scissors
Sharp knife or single-edged razor blade
Paper towels

PROCEDURES

A. Get out the preserved frogs you used in Section Three. If you are not starting with previously dissected frogs, refer to Investigation 3.1, Procedures A through E. The directions for dissection given there will show you how to prepare your specimen for this investigation.

B. Locate the heart and notice that some vessels are attached to the two thin-walled upper parts. A large vessel is attached to the thicker, muscular, lower part of the heart. The upper parts

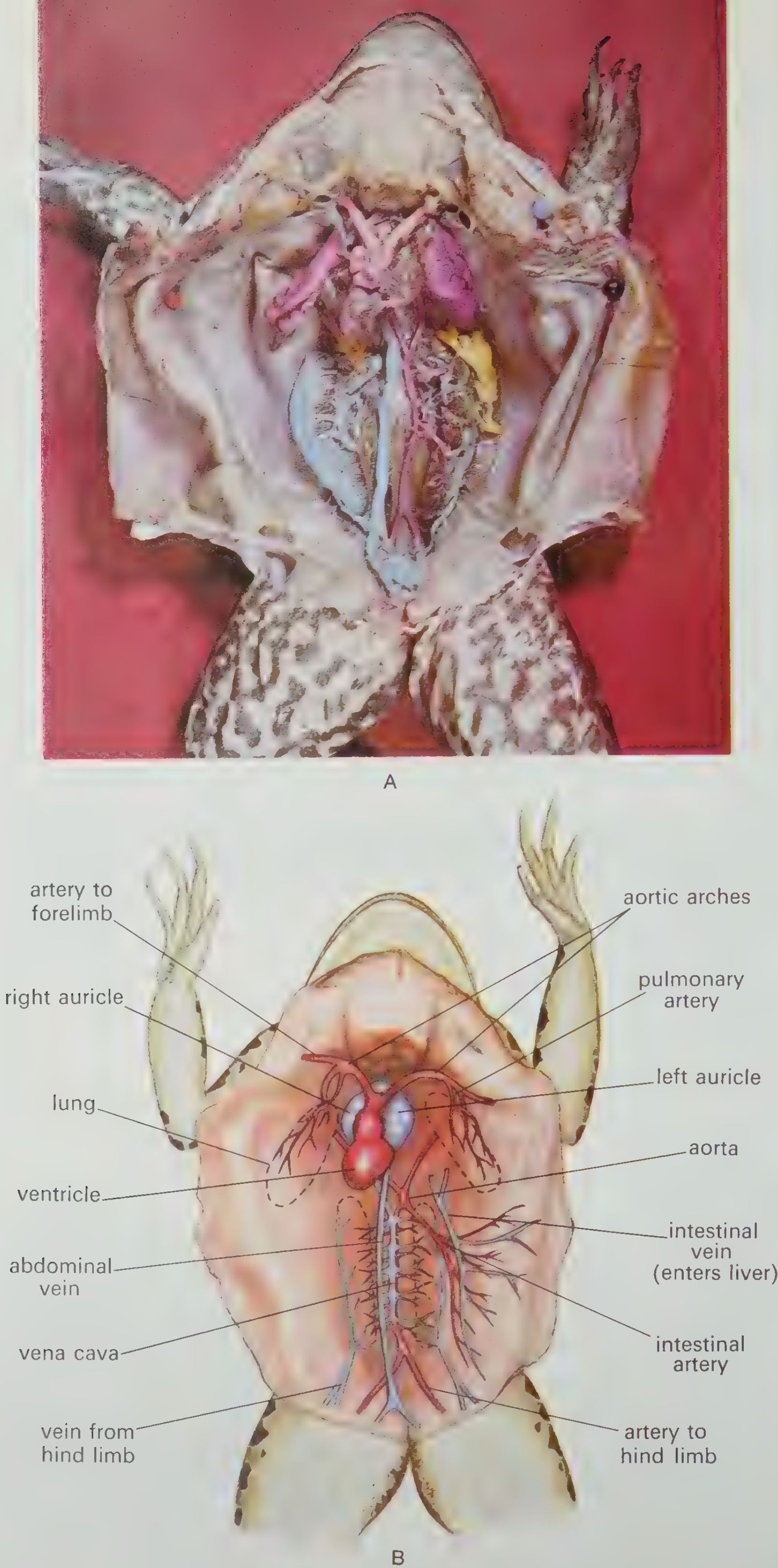


Figure 4 • 3.
A. A preserved frog, showing red arteries and blue veins.
B. Circulatory system of a frog.

are called auricles—the lower part the ventricle. Compare what you find with the labeled parts in Figure 4 • 3B. Can you find vessels in your own specimen that are not shown in this diagram? Study your specimen carefully and try to determine which vessels are arteries and which are veins.

C. As you can see, the vessels enter tissues or organs. To see more of the circulatory system requires very careful dissection. You have to follow the course of each vessel through tissue, and you can easily cut too deeply or separate tissues too rapidly. Do not assume that a vessel will continue in the same direction after it enters an organ or a tissue. Vessels frequently curve or branch.

ANALYSIS

On what basis could you decide whether a vessel was an artery or a vein?

Blood Circulation

The heart is a muscular organ that pumps blood. Rhythmic contractions of the heart force the blood out into arteries. Blood in the arteries is under high pressure, and arteries have thick walls. Blood in the veins is under less pressure than in the arteries, and the walls are thinner. However, both arteries and veins have walls that are too thick to let raw materials and waste materials diffuse through them. Capillaries have exceedingly thin walls, and it is through these walls that substances diffuse from the blood into the cells and from the cells back into the blood.

The capillaries are so widespread that no one cell in your body is more than a few cells away from them. After branching out, the capillaries come together again, forming veins. Each tissue or organ is drained by a vein that returns blood to the heart.

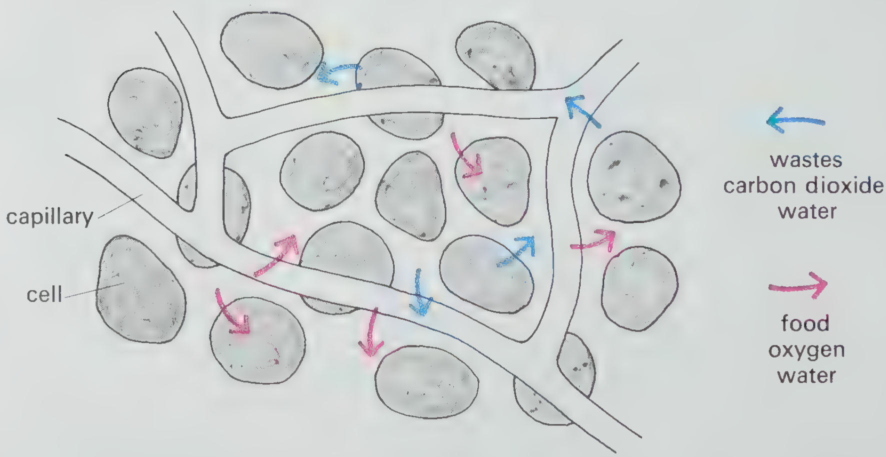


Figure 4 • 4. Diagram showing exchange of material between the capillaries and cells.

This complicated system is necessary because the cells of living things require various substances from the environment. As an organism gets larger, with more cells, the problem of getting food to all the cells becomes more difficult. To understand why, we might consider a large organism compared with a small one as being somewhat like life in a city compared with life on a farm.

Life in a city is, in some ways, more simple than it is in the country. Food may be delivered directly to the kitchen door. Garbage may be removed periodically, with little effort on the part of

city dwellers. The city supplies water directly to homes, and individuals are seldom bothered with repairing well pumps or maintaining water purity. While such services are taken for granted in a city, an individual living in the country may have to provide them himself. Thus the city dweller finds life easier only because complex service systems take care of his needs. Similar services—food delivery and "garbage" removal—must be provided to individual cells in a multicellular plant or animal. As a strike in a city may disrupt the life of the city, so a breakdown in the circulatory system may disrupt interactions between cells.

Blood is a complex mixture of cells, proteins, water, and other substances. Blood not only supplies materials and carries off wastes but also helps to defend the body from disease. Red blood cells carry oxygen. Several types of white blood cells defend the body against disease-causing bacteria. One of these is an amazing cell that moves out of the capillaries to engulf bacteria and then returns to the bloodstream. Another way the blood protects the body from disease is by interacting with proteins not normally found in the body. When such foreign substances are present, a reaction begins that causes the substances to clump together. If a foreign substance happens to come from a transplanted heart or kidney, the reaction may be serious. This is the "rejection reaction," a major problem in transplant operations.

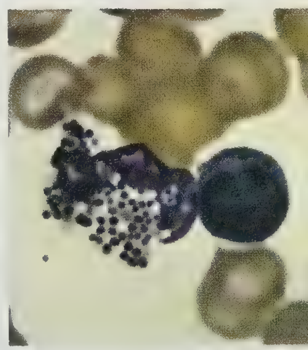


Figure 4 • 5. Blood cells from a patient with a bacterial infection. One white blood cell (*stained blue*) is normal. The other has many bacteria (*small blue spots*) near it.

Transfusions of blood are often necessary during major surgery and after accidents. But when blood of the wrong type is used, foreign proteins may cause a clumping reaction in the blood vessels of the receptor. This in turn can plug up the capillaries and cause a harmful reaction. Doctors make sure that correct blood types are used to prevent such a reaction from occurring.

The blood is a balanced mixture that contains all the materials necessary for the life of body cells. Living things are constantly exposed to change. The blood responds to such change in complex ways. You will study some of these responses in Section Six.

FOR CLASS DISCUSSION

Why do you think large animals have *both* a digestive system and a circulatory system?

Transport in Plants

The cells in plants have the same problems of access to the environment that animal cells do. In a large tree, water necessary for photosynthesis is absorbed through its roots from the soil. Yet it is used in leaves as much as 120 meters above the ground. Food is manufactured and used in leaves, but it is also needed by the roots. Large trees cannot depend upon simple diffusion from cell to cell for distribution of materials over great distances.

INVESTIGATION 4.3: Observing a Young Root

In most plants, only the roots absorb water. As you observe the growth of a young root, try to determine how its structure is related to the function of water absorption.

MATERIALS

Seeds, 10
Baby-food jar or petri dish
Paper towels

PROCEDURES

A. Place several layers of paper toweling in the bottom of the jar. Moisten the paper so that the top layer is quite wet (but there should be no water standing on top of the paper).
B. Spread the seeds about on the moistened paper. Cover the seeds with a layer of paper toweling. Sprinkle the top layer of paper gently with water.
C. Observe and moisten the seeds each day until they have germinated and the roots are about 3 cm long.

ANALYSIS

1. Which section of the root (base, tip, or middle) shows the fastest growth? How can you find out? Design an experiment that will give you an answer.
2. Describe the appearance of the growing root. Describe any changes in its appearance.

A B

C D

3. Illustrated on this page are some different kinds of roots. Discuss the possible functions of each.

Figure 4 • 6.

E

INVESTIGATION 4.4: A Stem

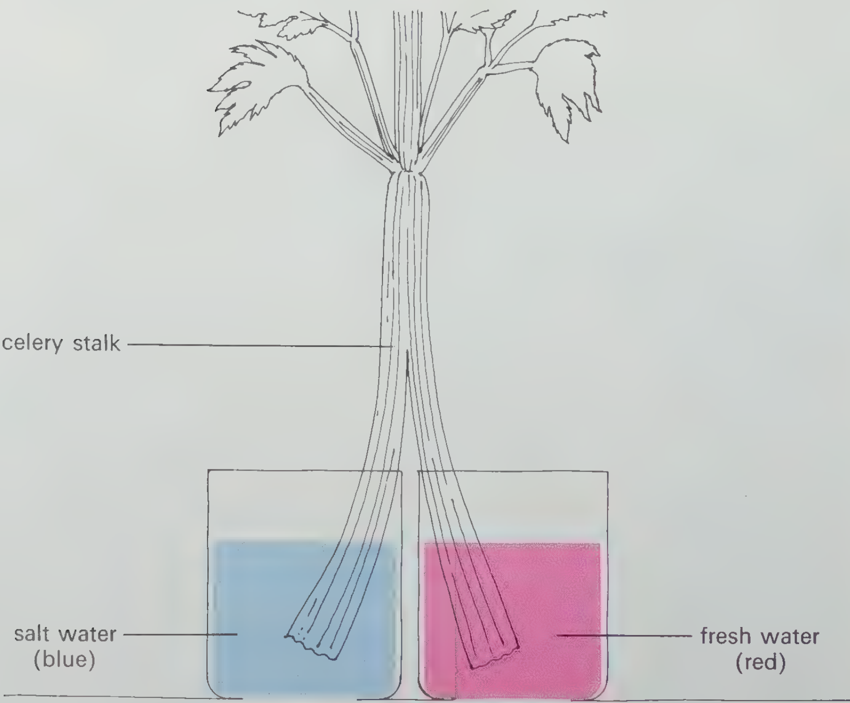
MATERIALS

Small jars or beakers, 2
Fresh celery stalks
Red vegetable dye
Blue vegetable dye
Table salt

PROCEDURES

A. Pour 50 ml of water into each jar.
B. Add 3 drops of red vegetable dye to one jar.
C. Add 3 g of salt and 3 drops of blue dye to the other jar and stir thoroughly.
D. Trim 8 cm off the bottom of the celery stalk. Carefully slit the cut end of the stalk and insert one side into the first jar, the other side into the second jar. Support the stalk loosely and observe (see Figure 4 • 7).

Figure 4 • 7. Setup for Procedure D.



ANALYSIS

1. Describe the appearance of the stalk and leaves above the jar containing red vegetable dye.
2. Describe the appearance of the stalk and leaves above the jar containing salt and blue vegetable dye.
3. Explain your observations.

Stems

A diagram of a celery stem is shown in Figure 4 • 8. Extending up the stem are cell bundles that consist of supporting cells (*fibers*), food-conducting cells, and water-conducting cells. Many of these bundles, called *vascular bundles,* are embedded in the *pith* of the stem. The pith consists of food-storage cells. The stem illustrated (Figure 4 • 8) is typical of plants that are called *herbs.*

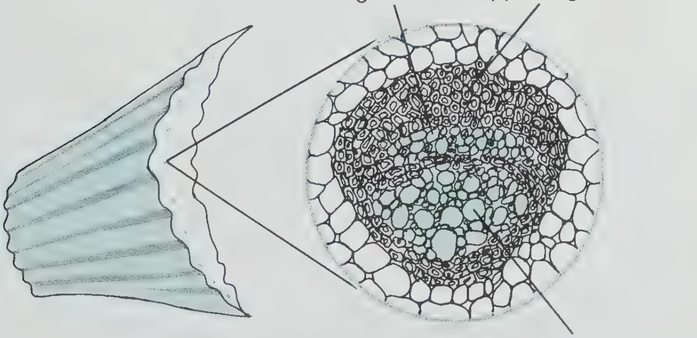


Figure 4 • 8. Cross section of a celery stem, showing an enlarged vascular bundle.

Other plants—including many familiar trees and shrubs—have *woody* stems. The conducting cells in the stem of a woody plant are arranged in rings rather than in bundles. The rings of water-conducting cells are found toward the inside of the stem. The ring of cells conducting food is found near the outside of the stem, just under the bark. Separating the water- and food-conducting cells is a single layer of dividing cells. As these cells divide, new conducting cells are produced—water-conducting cells to the inside, food-conducting cells to the outside. As a result of this growth,

the stem increases in diameter. The water-conducting cells toward the center of the stem eventually die and may fill up with woody material, which provides support for the tree or shrub (and perhaps support for your wooden house). As the stem continues to grow, the older food-conducting cells are pushed toward the outside of the stem (or trunk).

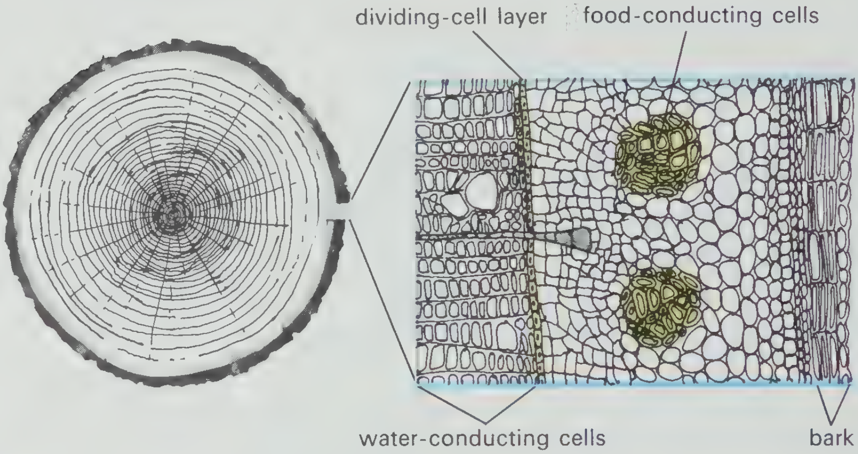


Figure 4 • 9. Cross section of a woody stem, with an enlarged section showing cells.

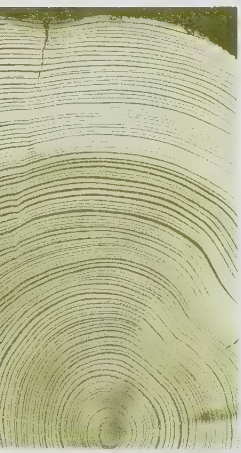


Figure 4 • 10. Cross section of a tree trunk.

When conditions of temperature, water, and light are right, the plant cells rapidly grow larger. When any of these conditions is not met, the cells do not grow as large—or they may not grow at all.

ANALYSIS

1. At what time of year do you think growing conditions would be best for the growth of plants with woody stems?
2. Assume that you live in an area that has great seasonal variation—warm, moist summers and dry, cold winters, for example. How could you find the age of a tree in such an area? How could you determine whether the weather in a certain year in the past was wet or dry?
3. In some areas of our country, porcupines do extensive damage to young trees. They gnaw off bark and underlying tissue in circles around the trees. Later, a tree's *roots* (and finally the entire tree) die. How may you account for this?

Leaves

Leaves require water, minerals, and carbon dioxide as well as light for photosynthesis. You have seen how roots are specialized to take in water and minerals. Stems are also specialized—to carry water and minerals up to leaves. Stems and roots, being alive, also require food. And you have seen that there are food-conducting tubes leading down through stems and roots.

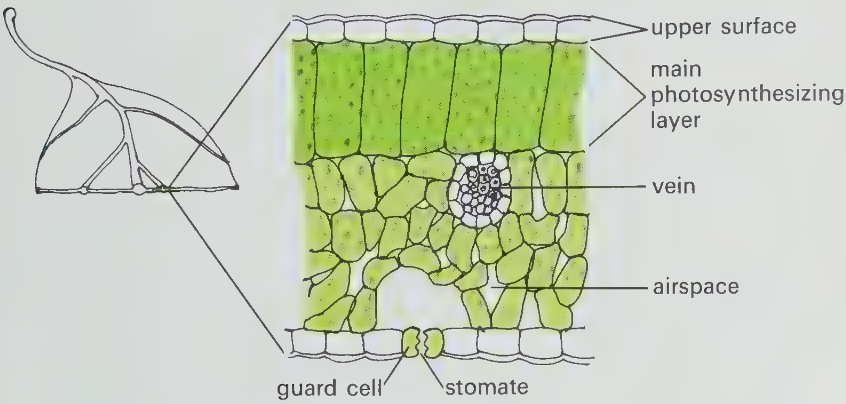


Figure 4 • 11. Cross section of a leaf, showing arrangement of cells.

A leaf has a variety of cells with different functions (see Figure 4 • 11). The outside of the leaf is covered with flat, transparent, sometimes waxy cells. There are openings called *stomates* among the waxy surface cells. Usually most of the stomates are found on the bottom surface of the leaf. The size of the openings is regulated by *guard cells*. The stomates let water vapor out of the leaf and carbon dioxide gas in. There may be many thou-

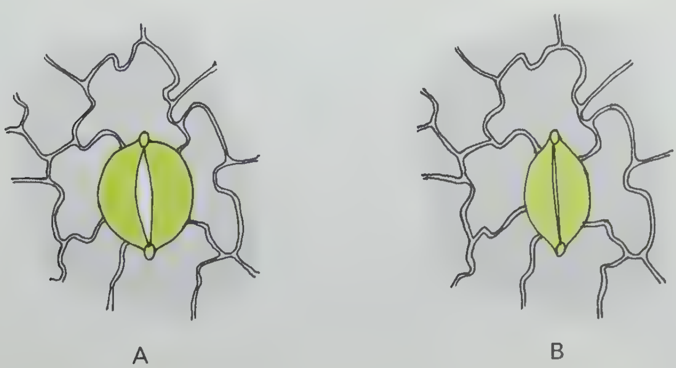


Figure 4 • 12. As guard cells on the leaf's surface change in size, the stomate is opened (A) or closed (B).

sand stomates per square cm of leaf surface. If all of them were wide open, the evaporation of water from the leaf would be very rapid. This could prove fatal to the plant, so guard cells may change size, regulating the opening and the rate of water loss.

Just under the upper surface is a layer of *closely* packed cells that carry on photosynthesis. The cells in the lower half of the leaf are *loosely* packed and form caverns containing moist air.

ON YOUR OWN: A Model for Root Transport

MATERIALS

Dialysis membrane
Colored sugar solution
6-mm OD ("outside diameter") glass tubing
1-hole rubber stopper, No. 2
Beaker
String
Funnel

PROCEDURES

A. Securely tie off one end of a 15-cm piece of water-soaked dialysis membrane. Fit the open end of the membrane onto a 1-hole stopper (No. 2 or 3) and tie securely with several winds of string. (NOTE: *This connection should be watertight.*)
B. Using a small funnel, fill the membrane with colored sugar solution. Insert a piece of glass tubing about 1 meter long into the stopper.
C. Submerge the membrane in a beaker of water and fasten the tubing in an upright position. Observe the setup (often called an osmometer) periodically for the rest of the period.

ANALYSIS

1. How might you account for the results you observed?
2. Describe several weaknesses in this model of a root-transport system.

ON YOUR OWN: Capillary Action

The transport system extends from the root through the stem and reaches to the tips of the leaves. You can make a model that illustrates some of its functions.

MATERIALS

- 6-mm OD glass tubing, about 60 cm
- Bunsen burner or portable propane torch
- Triangular file
- Baby-food jars or beakers
- Colored water
- Metric ruler

PROCEDURES

A. Cut several 15-cm lengths of glass tubing. Holding one end of a length with the fingertips of one hand and the other end with the fingertips of the other, place the center in the tip of the blue flame of a Bunsen burner.

B. Rotate the tube gently between your fingers so that it is heated equally on all sides.

C. Continue heating the center of the tube until it just begins to sag. Then quickly remove the tube from the flame and pull on the ends. Stretch the tubing as far as possible (Figure 4 • 13). If this is carefully done, the center will not break but will be stretched out so the tube is long and thin.

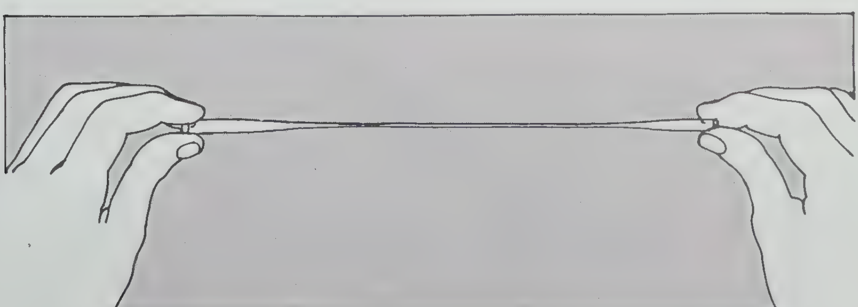
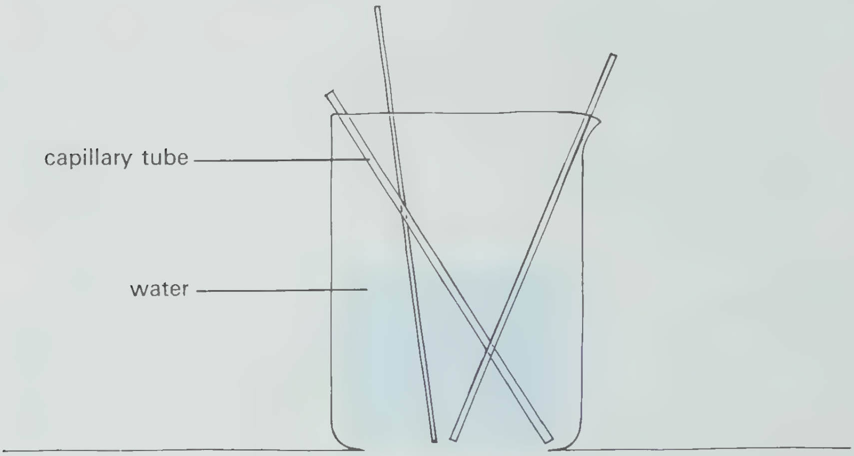


Figure 4 • 13.

D. When it is cool, cut the thin piece of tubing into 20-cm lengths. (CAUTION: *Do not handle the heated tubing until it is cool.*)

E. Stand several of the tubes in baby-food jars containing colored water (Figure 4 • 14). Observe and record the results.

Figure 4 • 14.



ANALYSIS

1. How might you explain the results you observed?
2. What structure in a plant might fulfill a similar function?

ON YOUR OWN: Surface Area and Evaporation

An acre of corn plants will release about 1,135,000 liters (300,000 gallons) of water into the air per season. This evaporation takes place through the leaves of the plants. What relationship do you think exists between the surface area of a leaf and the loss of water from that leaf?

MATERIALS

Paper toweling
Drinking straws, 2
Baby-food jars (or other small jars), 3
Scissors
Metric ruler
Graduated cylinder

PROCEDURES

A. Cut two drinking straws in half.
B. Cut out four 15-cm x 4-cm rectangles of paper toweling.
C. Fold each piece of toweling several times to form long, narrow pieces that will fit inside each section of drinking straw.
D. Slide a piece of folded toweling into each section of drinking straw. Unfold the exposed part of each piece of toweling to form a series of four "leaves" (Figure 4 • 15).

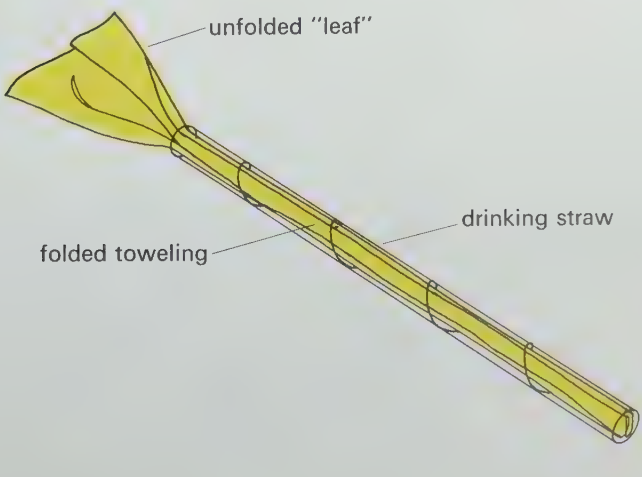
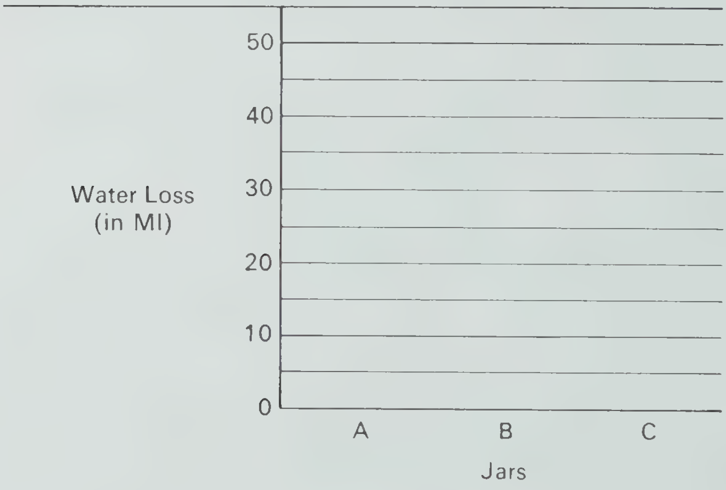


Figure 4 • 15. Setup for Procedure D.

E. Label the three jars A, B, and C. Pour 100 ml of water into each jar. Place one leaf in Jar B. Place the three remaining leaves in Jar C.

F. After 24 hours, measure the amount of water left in each jar. Record these data in your notebook. Next, determine the number of ml of water that have *evaporated* from each of the jars. Copy in your notebook the graph outline below. To plot these data, prepare a bar graph by drawing a solid vertical line representing the amount of water that evaporated from each jar.

Figure 4 • 16.



ANALYSIS

1. What is the reason for having Jar A?
2. What relationship exists between the surface area of the model leaves and the evaporation of water?
3. Assume that a similar relationship is found in real leaves. What kinds of leaves would be most beneficial for plants living in hot desert areas? Explain your answer.

The Whole Plant

Imagine a continuous column of water extending from the roots to the leaves of a plant. The root exerts some pressure on the bottom of the water column, as you saw in the root-model investigation on page 100. There is some small lift imparted to the column of water because of the small diameter of the water-transporting cells—recall the capillary-action investigation on page 101. The final force lifting the column of water comes from evaporation from the leaves above. Recall investigating surface area and evaporation on page 103: a lot of water was lost per square cm of leaf surface. Many biologists think this last force, sometimes called transpiration instead of evaporation, is the most important, but all three forces are necessary. Root pressure, capillary action, and the pull of transpiration from the leaf combine to lift columns of water to the tops of redwood trees 120 meters tall.

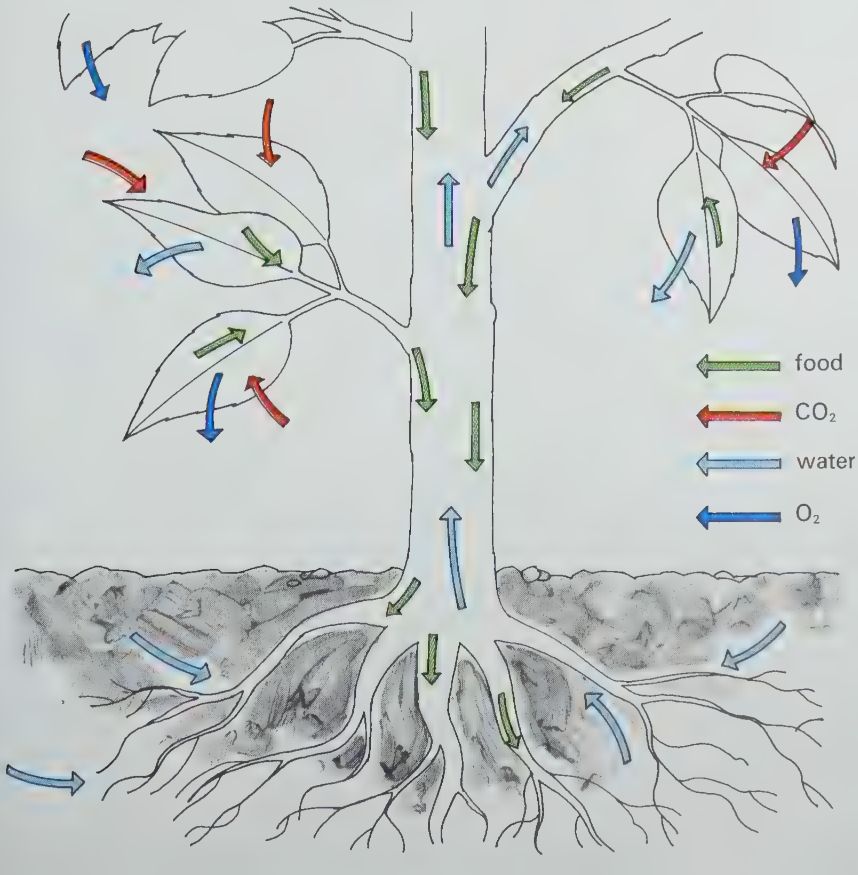


Figure 4 • 17. A summary of transport in a plant. NOTE: *Food* (green arrows) *is produced and used within the plant. Water* (light blue arrows), *which is taken in by the roots, contains minerals that are used within the plant.*

This moving water carries raw materials for photosynthesis and prevents a plant from wilting. Food is made in the leaf. Some of it is used by the leaf, and the excess is stored in the spongy cells. When the spongy cells can store no more, excess food is changed into soluble sugar and transported down to the stem and roots in the food-conducting cells. Tasty maple syrup is made from sugar-rich sap which rises up sugar-maple trunks in the spring (for sugar maple, see Figure 2 • 9).

A plant is a community of cooperating cells. Stems and branches hold the leaves in place, and they are exposed to sunlight. Roots anchor the plant and absorb minerals and water. And leaves, stems, and roots all function in transporting substances. The balance among water, minerals, oxygen, and carbon dioxide is maintained by closely coordinated processes. For example, if the plant has too little water, the guard cells may close the stomates. This will prevent further loss of water. When the plant has restored the water balance, the guard cells will open the stomates again.

Extending Your Knowledge

Heart failure is the cause of over 25 percent of all deaths of American males, and the incidence is rising among American females. This percentage is substantially higher than it is in most other countries. What factors in our way of life may lead to a high occurrence of heart disease?

Some data to consider in this problem might be:

1. The function of heart muscle is in general similar to the function of other muscles in your body.
2. The total length of the circulatory system may be increased approximately a mile with each additional pound of body fat added to a person's weight.
3. Emotional stress may cause small arteries to constrict, pulse rate to increase, and the heart output to increase—all of which may increase blood pressure.

SECTION FIVE

How Food Is Used

Energy from Food

You have found that through the process of digestion, food molecules become available for absorption through the cells lining the digestive system. The food molecules are then transported by the circulatory system to various cells where they are used for energy and growth.

An appropriate question at this point might be: How much energy can various kinds of food provide? One way of measuring the energy in food is to determine the amount of heat produced when food is burned. This heat energy is measured in units called *calories*. A calorie is defined as the *amount of heat needed to raise the temperature of 1 g of water one degree centigrade*. For example: Suppose that all the heat from a burning peanut was transferred to a flask containing 10 g of water. The water temperature rose three degrees centigrade. How many calories were absorbed by the water? To answer this question, multiply 10×3.

$$\text{number of calories} = 10 \times 3 = 30$$

How many calories are required to raise the temperature of 25 ml of water four degrees centigrade? Since 1 ml of water weighs 1 g, 25 ml of water weighs 25 g. Therefore, number of calories $= 25 \times 4 = 100$.

PRACTICE PROBLEMS

Calculate the number of calories required to cause the temperature change in each of the following problems:

1. The temperature of 5 g of water is raised 4°C.
2. The temperature of 12 ml of water is raised 3°C.
3. The temperature of 25 ml of water is raised 2°C.

ANSWERS TO PRACTICE PROBLEMS

1. Number of calories $= 5 \times 4 = 20$
2. Number of calories $= 12 \times 3 = 36$

3. Number of calories $= 25 \times 2 = 50$

PROBLEMS

Calculate the number of calories absorbed by water for each of the following five foods that were burned:

Food	*Volume of Water in Milliliters*	*Beginning Temperature in Degrees C*	*Ending Temperature in Degrees C*
1	25	31	35
2	36	26	28
3	10	25	75
4	15	40	45
5	75	25	30

Figure 5 • 1.

INVESTIGATION 5.1: Measuring Energy in Food

In this investigation you will have an opportunity to determine the number of calories contained in some solid foods.

MATERIALS

125-ml Erlenmeyer flask
Test-tube holder
Graduated cylinder
Cork and sharp pin
Solid foods (walnuts, peanuts, Brazil nuts)
Scale
Thermometer (C)
Coffee can
Masking tape
Aluminum foil

PROCEDURES

A. Select a food to test for caloric content. Cut the food into small pieces. Weigh each small piece. Select a sample that weighs about 0.3 g or less and record its weight in a chart similar to the one shown in Figure 5 • 2.

B. Pour 50 ml of water into the flask. Insert the flask into the coffee can as shown in Figure 5 • 3. Hold the flask in place by clamping a test-tube holder to the top of the flask above the top of the coffee can.

Figure 5 • 2.

Kind of Food Burned	*Beginning Weight of Food Sample in Grams*	*Ending Weight of Food Sample in Grams*	*Volume of Water in Ml*	*Beginning Temperature in Degrees C*	*Ending Temperature in Degrees C*	*Temp. Change in Degrees C*	*calories*

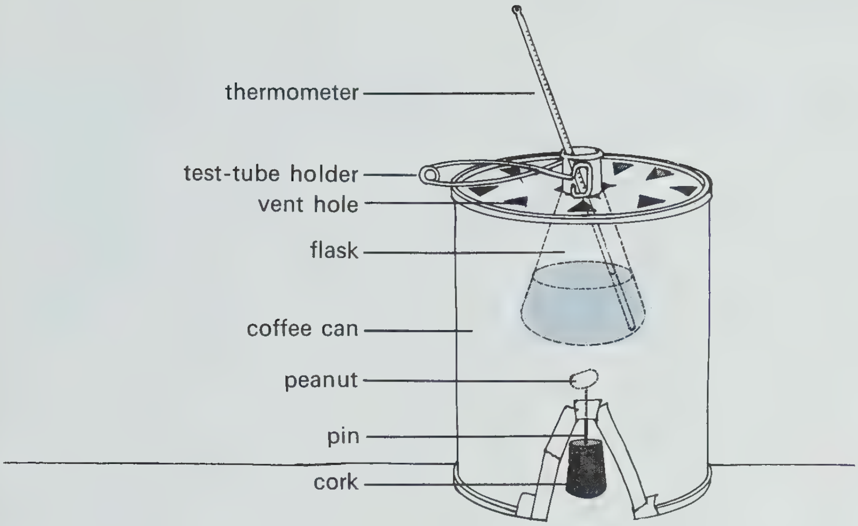


Figure 5 • 3.
Setup for
Procedures B–E.

C. Wrap a cork in aluminum foil. Insert the *blunt* end of a pin into the cork. The sharp end of the pin will hold the food to be burned. Put a weighed piece of food on the pin. Place the pin and food under the can and flask as illustrated in Figure 5 • 3. The food should be about 2 cm under the bottom of the flask.

D. Measure and record the temperature of the water in the flask before beginning.

E. Bring the piece of food out and use a match to light it. As soon as it is burning, push it under the bottom of the flask. When the food has burned, record the highest temperature that is reached by the water in the flask.

F. Remove the pin and any ash that is left. Weigh the ash and record its weight as the final weight of the food.

G. Calculate and record the number of calories released by the burning piece of food.

Calories per Gram

Sometimes it is useful to calculate the calories *per gram* of food. Suppose that burning a piece of walnut weighing 0.25 g produces 250 calories of heat energy and leaves 0.05 g of ash. To calculate the number of calories per gram of food burned, subtract the final weight from the beginning weight. Then divide the number of calories produced by the number of grams burned. Since you started with 0.25 g of walnut and ended with 0.05 g of ash, then

$$0.25 \text{ g} - 0.05 \text{ g} = 0.20 \text{ g of walnut burned.}$$

Dividing calories by grams of walnut burned, you see that

$$250 \text{ cal} \div 0.20 \text{ g} = 1250 \text{ cal per g.}$$

PRACTICE PROBLEMS

Using the following data, calculate the number of calories per gram of food burned:

1. Volume of water = 20 ml
   Ending temperature of water = 25°C
   Beginning temperature of water = 23°C
   Beginning weight of food = 0.3 g
   Ending weight of food = 0.1 g
2. Volume of water = 50 ml
   Ending temperature of water = 35°C
   Beginning temperature of water = 30°C
   Beginning weight of food = 0.3 g
   Ending weight of food = 0.2 g

ANSWERS TO PRACTICE PROBLEMS

1. *Step one:*
   20 ml of water weighs 20 g
   25°C − 23°C = 2°C
   Number of calories = $20 \times 2 = 40$

Step two:
Beginning food weight = 0.3 g
Ending food weight = 0.1 g
Difference = 0.2 g of food burned
Step three:
40 cal ÷ 0.2 g = 200 cal per g

2. *Step one:*
50 ml of water weighs 50 g
35°C − 30°C = 5°C
Number of calories = 50 × 5 = 250
Step two:
Beginning food weight = 0.3 g
Ending food weight = 0.2 g
Difference = 0.1 g of food burned
Step three:
250 cal ÷ 0.1 g = 2500 cal per g

Meaning of "Kilocalorie"

Energy can also be measured in another kind of unit called a *kilocalorie*. One kilocalorie is equal to 1000 calories. A kilocalorie is sometimes written "Calorie" (with a capital C).

To convert calories/gram to kilocalories/gram, divide by 1000. For example: 1250 cal/g = 1.250 kcal/g. Most people mean kilocalories/gram when they speak of food energy using the word "Calorie."

INVESTIGATION 5.1: Measuring Energy in Food

(continued)

PROCEDURES ***(continued)***

H. After doing the practice problems, calculate the kilocalories per gram of the first food sample.

I. Repeat Procedures D through G (page 111) and Procedure H with the remaining food samples. Be sure to use a cool flask and change the water each time. Determine the average number of kilocalories per gram in the food you burned.

J. Prepare a chart (similar to Figure 5 • 4) that shows the number of kilocalories per gram in each of the three nuts named in that figure. Compare your results with the results of the other teams.

Figure 5 • 4.

Food Burned	*Kilocalories/Gram*
Peanut	
Brazil Nut	
Walnut	

ANALYSIS

1. What were some sources of error in this investigation?
2. Why might you get a result that does not agree with values given in books?

Energy, Weight, and Work

The word "energy" is a common one that we have used often. What does it mean? Write down what you think energy is, what it does, and where it comes from.

Even while you sleep, your cells use energy. You also lose some energy as heat through your skin. There is a minimum amount of energy necessary to maintain life. The average minimum energy requirement for a person your age is about 1500 kilocalories per day.

The energy necessary for physical activity is directly related to the amount of work done. For example, it takes about 11 times as many kilocalories for a person to swim rapidly as it does for that person to wash dishes for the same length of time. Many more muscles are involved in swimming than in washing dishes.

The weight of a person is also important in determining the energy necessary for physical activity. For example, it would take more kilocalories for an 80-kg (176-pound) person than for a 60-kg (132-pound) person to do the same job. Why do you think this is so?

The energy needed for a few different kinds of activity are listed in terms of kilocalories per kilogram of body weight per hour in the following figure:

Activity	*Kilocal / Kg / Hr*	*Activity*	*Kilocal / Kg / Hr*
Swimming	11.5	Dishwashing	1.0
Running	10.6	Preparing Food	1.0
Dancing	7.6	Eating	0.4
Playing Ping-Pong	4.4	Writing	0.4
Walking	2.0	Watching Television	0.4

Figure 5 • 5A.

If you weigh 50 kg (110 pounds) and dance for two hours, you will use 7.6 kcal $\times$ 50 kg $\times$ 2 hr, or 760 kcal. If, however, you weigh 40 kg (88 pounds), you will use only 608 kcal. The number of kilocalories that you need for a day's activities may be

Figure 5 • 5B. How many hours of writing would it take to use the same amount of energy as is needed to play Ping-Pong for one hour?

calculated from this kind of chart. During an active school day you may use up as much as 2000 kcal. Adding this amount to the 1500 kcal needed just to maintain your basic life functions, you find you would require about 3500 kcal per day.

The energy in kilocalories that we need for daily activities comes from the food we eat. If your daily food intake amounts to 3500 kcal, and if you use 3500 kcal a day, you should neither gain nor lose weight. If you eat food that contains 4000 kcal a day and use 3500 kcal, you gain 500 kcal a day. As is true of nearly all plants and animals, this extra energy is found in fat or starch.

If you use more kilocalories than you take in during a day, you may lose weight because you use some of your stored energy. In general, you gain weight if you eat food containing more kilocalories than you use in a day. You lose weight if you eat food containing fewer than you use in a day.

When an animal needs energy, the first food that it will use is sugar, followed by starch. If after that the body is still using more energy than the diet provides, fat and then protein will be used. When an animal has used up its stored fat and starts to use its protein (such as muscle), it is starving.

INVESTIGATION 5.2: Human Calorimetry

Some of the calories contained in the food you eat are lost as heat energy. Is there a way to determine the amount of energy lost in terms of calories?

To answer this question, design and carry out an experiment to determine the approximate number of calories of heat energy given off by your hand over a five-minute period. Then determine the rate of calorie loss *per minute*.

You should be able to do this without much help from your teacher, providing you think carefully about how you will carry out the experiment. Use water in some way to determine temperature change. Include a control.

Extending Your Knowledge

It has been suggested that tanks of green algae be included in the manned spacecraft that go on long flights to other planets. The tanks are to be lighted continuously, and air from the cabins is to be bubbled through the water the algae are growing in. One criticism of this plan is that the astronauts might die if the water in the tanks accidentally became contaminated.

What do you think is the purpose of the algae tanks?

Can you think of another kind of "spaceship" that includes algae tanks which serve a similar function?

SECTION SIX

Interacting with the Environment

Every animal must be able to sense (detect) changes in the environment. This is true of simple organisms whose bodies are only one cell. It is also true of organisms as large and complex as elephants and human beings. What would happen to an animal if it could not detect what was going on in its environment and do something about it? An organism not only must sense environmental changes; it also must react to those changes to ensure its well-being and perhaps its survival. You can easily imagine how this would affect its ability to obtain food, reproduce, escape predators, and find shelter.

Most of us only think of sensing and reacting to changes in the *external* environment. But a multicellular organism also has an *internal* environment. Changes inside an organism must also be sensed and reacted to so that the delicate cells can be kept in a constantly favorable environment.

Most of the investigations in this section concern human beings. In humans (and most large animals) reacting occurs in two ways. One is automatic: reactions occur *without* conscious control. The second way is not automatic: reacting occurs *with* conscious control.

At this point you might ask: How are we able to sense changes in the environment? In humans and many other animals there are special structures called sense receptors located in the eye, ear, nose, tongue, and skin. These allow us to see, hear, smell, taste, and feel pressure and pain. In addition there are receptors located inside the body that sense changes in position, blood pressure, breathing, and so on. Anything that can be sensed by a receptor is called a *stimulus*. When a stimulus (plural: "stimuli") acts upon a receptor, a message is relayed through nerves to the spinal cord and/or the brain. If a reaction is to occur, a message is sent *from* the spinal cord or brain to a muscle or a gland. The muscle then contracts, or the gland secretes a chemical.

Plants, too, have structures and chemicals that allow them to respond to certain stimuli; they will be considered later in this section. For the most part, however, you will investigate how stimuli are received and how reactions occur and learn how internal balance is maintained in one kind of organism—you.

A Model Control System

To help you understand how something is detected and then responded to, we will use a model. This model will be the apparatus that maintains the water at the proper level in a watering trough (see Figure 6 • 1). As the water level goes down, the float goes down with it. The float is attached to a valve in a water pipe; when the water level falls far enough, the valve is opened and water enters the trough. As the water rises, the float also rises. The valve and float are attached in such a way that the valve will close when the water reaches the proper level.

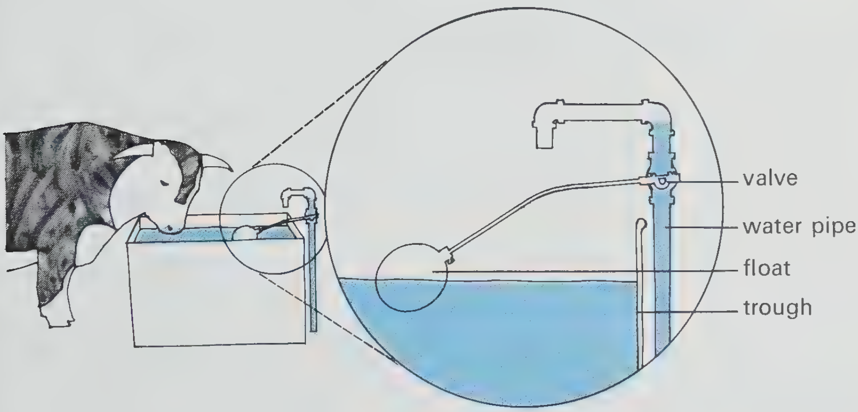


Figure 6 • 1. Diagram of a system to control water level.

Let us analyze the important parts of this model. There is a substance to be maintained at a certain level—the water. There is a mechanism that regulates the flow of the substance—the valve in the water pipe. And there is a sensor mechanism (the float) that detects the level of water in the trough. As animals drink from the trough, the water level goes down. When the water level lowers to a certain point, the valve opens and the water pours in, raising the level. Such a system will maintain the water at a fairly constant level in the trough.

To understand how human control systems maintain internal balance, you need to learn more about the nervous system and about some special chemicals—chemicals that, together with nerves, coordinate all the various systems of the body. Throughout this section you will study and investigate how organisms sense and react to their internal and external environments and thus maintain internal balance. As you do, remember the simple model showing how the water level is maintained in a watering trough. Look for the parts that compare with the model. What is to be controlled? What does the controlling? What does the sensing?

INVESTIGATION 6.1: Light Intensity and the Eye

On a bright summer day, a great deal of light reaches your eyes. If you awake late at night, you may see objects in your bedroom. Yet there may be a hundred thousand times less light in your bedroom than there was outside during the bright day. Your eyes function in both extremes and in many in-between conditions of light intensity. The dark opening in the center of the colored part (iris) of your eye is the pupil. Let's investigate the pupils of your eyes and their reactions to light. Try to determine whether or not they respond automatically to light.

MATERIALS

Light source (small flashlight)

PROCEDURES

A. You are to take turns observing and being observed. Have one member of your team close his eyes for about ten seconds. When he opens them, carefully watch what happens to the size of his pupils. Record your observations in a chart like the one in Figure 6 • 2.

B. Have the same student close both eyes again for about ten seconds. Have him hold his hand or a card by his nose so that a

Observation	*Description of Pupil Response*
Procedure A	
Procedure B	
Procedure C	
Procedure D	

Figure 6 • 2.

light striking the left eye will not strike the right one (see Figure 6 • 3). Have him open both eyes. Shine the light from a flashlight into his left eye. Observe the left eye and record the response of the student's pupil.

C. Repeat Procedure B. This time observe the right eye instead of the left. Record your observations.

D. Now have the student concentrate on trying to control the reactions of his pupils as you repeat Procedures A and B. Are there any differences?

E. Repeat Procedures A, B, and C with other students and other observers. Record your team's results.

Figure 6 • 3. Shading one eye as described in Procedure B.

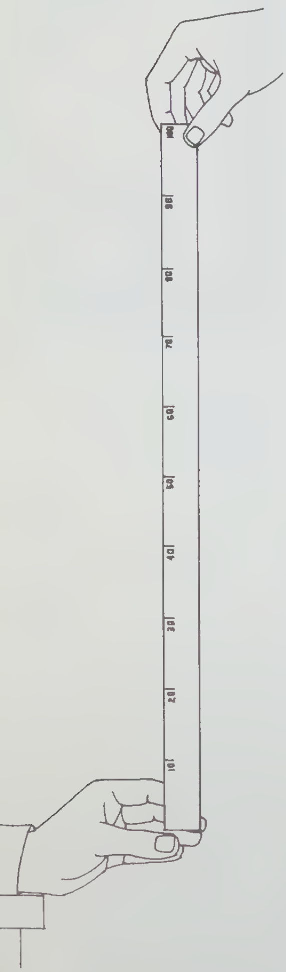
ANALYSIS

1. Is there any evidence that the pupil reflex is an automatic response?
2. Compare the pupil responses you observed in Procedure B with those you observed in Procedure C. How might you explain these results?
3. List other similar responses with which you may be familiar.

INVESTIGATION 6.2: Reaction Time

A person driving a car sees a dangerous situation ahead and steps on the brake pedal. A certain amount of time elapses between seeing the situation and reacting to it—stepping on the brake. This time is called *reaction time*. Few people realize how long their reaction time is.

Figure 6 • 4. Carrying out Procedure A.



MATERIALS

Meterstick

PROCEDURES

A. Form teams of two students. One student should drop a meterstick and the other catch it. Before it is dropped, the meterstick should be held at the 100-cm end between the thumb and forefinger. Have the student catching the stick rest his or her arm on a solid object, such as a desk, with his hand extending over the edge. His thumb and forefinger should be slightly separated, held around the zero-cm end of the meterstick (see Figure 6 • 4).

B. The student holding the stick should choose when to drop it. The student catching the stick should not know when it is to be dropped. He should wait until he sees it move, then try to catch it by closing his fingers.

C. Repeat the test five times. Record the distance the stick falls on each trial. Determine the average distance for the five trials.

D. Figure 6 • 5 shows the time needed to catch the stick as it falls various distances. Refer to this figure and determine your reaction time by matching the average distance with the times given on the right.

E. Repeat Procedures A–D, having another student catch the stick.

ANALYSIS

1. What must happen in various parts of your body before you can catch the meterstick?

Average Distance the Meterstick Falls	*Time Required to Catch the Stick (Reaction Time)*
10 Cm	0.14 Sec
12	0.16
14	0.17
16	0.18
18	0.19
20	0.20
22	0.21
24	0.22
26	0.23
28	0.24
30	0.25
32	0.26
34	0.27
36	0.28
38	0.29
40	0.30

Figure 6 • 5.

2. Why may a driver's reaction time in stepping on the brakes be slower than yours is in catching the stick?

PROCEDURES *(continued)*

F. Repeat Procedures A–E. Have the student catching the stick say the multiplication tables, starting with "6." For example, $6 \times 1 = 6$, $6 \times 2 = 12$, and so on. Again, try to drop the stick when it is not expected.

ANALYSIS *(continued)*

3. What effect does thinking of the multiplication tables have on reaction time?
4. What are some other things that might influence reaction time?

The Nervous System

The responses we have just studied are made possible by the nervous system. This system consists of the brain, spinal cord, and nerves as well as sensory receptors. Nerves are found throughout the body. Some carry messages to the spinal cord and brain. Others carry messages from the brain and spinal cord to all other parts of the body.

One set of nerves makes it possible for the muscles of the body to move when you wish them to. Another set regulates things we cannot consciously control, such as heartbeat, expansion or contraction of blood vessels, and operation of the digestive tract. Such control is automatic.

Nerves that carry messages from the brain or spinal cord to a target (muscle, gland, or other organ) and cause a reaction there are called *motor* nerves. Nerves that carry messages about changes in an organ to the spinal cord or brain are called *sensory* nerves. In general we may say that when a sensory nerve is stimulated, the nerve message that it transmits runs to a "switchboard" in the spinal cord. The "switchboard" can send the message in several directions. The message may activate a motor nerve and then a spinal nerve that goes on to the brain. Or it may go directly to the brain, which may in turn activate a motor nerve. When the message reaches the brain, it passes another "switchboard." The message may be directed to a conscious part of the brain or to an unconscious (automatic) part. In either case, it will be acted upon. The action may be the movement of a leg muscle, the speeding up of the heart, or the expanding of the small arteries in the fingers. Sensory nerves play an important part in starting a response to environmental change.

Some Sensory Nerve Responses

One of the wonders of being alive is the way in which we perceive things in our environment. The pleasure we derive from tastes, sounds, and sights has inspired poets, artists, composers, and all who pay attention to their surroundings. Although we appreciate these senses, few of us are aware of their limitations. Let us con-

sider one sense—the sense of pressure in your skin—and some of its limitations. Your skin is supplied with sensors that detect changes in pressure. When pressure is exerted against these, an impulse travels to your brain and you feel the pressure. Consider the pressure receptors in your arm. If you lean your arm on the top of a desk, you can feel pressure wherever your arm comes in contact with the desk. However, pressure receptors are not evenly distributed over your body. Where do you think they would be most abundant?

INVESTIGATION 6.3: Mapping Pressure Receptors

MATERIALS

Straight pins
Large cork
Metric ruler

PROCEDURES

A. Place two pins in the cork so that the heads are about 2 cm apart. See Figure 6 • 6. Tell your teammate not to watch, and gently touch the heads of both pins at the same time to the inside (palm side) of his forearm. Ask him how many pins he feels. Move the two pins to different positions on the inside of his forearm. If he feels two pins, two pressure receptors must have been stimulated. If he feels just one pin, only one pressure receptor must have been stimulated. Move the pins farther apart if he reports feeling one pin. Move them closer together if he feels two points. Each time measure the distance between pins in millimeters.

Figure 6 • 6. Setup for Procedure A.

B. Copy Figure 6 • 7 in your notebook. For each area tested, record the shortest distance between pins that made it possible for two points to be felt.

Figure 6 • 7.

Area Tested	*Inside of Forearm*	*Outside of Forearm*	*Palm of Hand*	*Back of Hand*
Shortest distance between pins at which two points are felt				

ANALYSIS

1. Is the distance between pressure receptors the same all over the arm and hand?
2. Is it possible that you are unable to sense some changes in the environment? Give examples.

INVESTIGATION 6.4: Sensing Temperature

Some time when you were feeling ill, your mother may have put her hand on your forehead to find out if you had a fever. This investigation should help you decide how accurate this method of sensing temperature is.

MATERIALS

Large glass or metal containers, 3
Ice
Hot water
Thermometer

PROCEDURES

A. Label the containers A, B, and C. Pour water—at room temperature—into Container B. In Container A mix tap water and hot water until you have a mixture that is about 55°C. In Container C mix tap water and ice until you have a mixture that is about 10°C.

B. Line up the containers in front of you. Place your left hand in Container A, your right hand in Container C. After about three minutes remove both hands and place them in Container B.

C. Describe and record the sensation in each hand.

ANALYSIS

Do the temperature sensors in your hand indicate actual temperature or just changes in temperature? Explain your answer.

INVESTIGATION 6.5: An Afterimage

MATERIALS

White paper

PROCEDURES

A. Using a pencil, draw a small dot in the center of a sheet of white paper.

B. Stare hard at the dot in the center of Figure 6 • 8 for 10 or 20 seconds. Then immediately shift your eyes to the dot on the white paper. Stare at the dot for 10 seconds. What do you see?

C. Sometimes the sight of things around the figure will interfere with clearly seeing an afterimage. One way to eliminate this interference is to roll some paper into a tube, shut one eye, and hold the tube up to the other eye. Move the tube so you can see only the figure. Repeat Procedure B. Record any differences.

Figure 6 • 8.

ANALYSIS

1. How can you explain the occurrence of an afterimage?
2. Can you think of a practical use for afterimages?

Figure 6 • 9. Using a paper tube as in Procedure C, stare at the dot in each drawing and describe the afterimage.

FOR FURTHER ACTIVITY

Draw different outlines in black, and, with your friends, test them for afterimages. Try using various figures in red or green, or vary the background color. Do all colors produce afterimages? Is the color the same in an afterimage as in the original figure?

ON YOUR OWN: Fingertip Test

Coordination of muscular and nervous control may be directed by sight. In the absence of sight, it may be accomplished in other ways. The following investigation may help demonstrate one way.

PROCEDURES

A. Raise your arms in front of you, with the tips of your left and right index fingers meeting.
B. Draw your hands apart until they are separated by a distance of about 60 cm (2 feet). Bring them slowly together until the tips of your index fingers meet again. Repeat this two or three times.
C. Now close your eyes, draw your hands apart as before, and then bring them together again. Did your fingertips meet? Try this several times.
D. Repeat Procedures B and C several times.

ANALYSIS

1. How was your action coordinated when your eyes were open? Was it coordinated as a result of sensing your external or your internal environment?
2. How was your action coordinated when your eyes were closed? Was it coordinated as a result of sensing your external or your internal environment?

FOR FURTHER ACTIVITY

A similar investigation may be performed in the following way: Draw a circle about the size of a penny on a piece of paper. Then hold a pencil vertically, with the point in the center of the circle. Raise the pencil about 40 cm above the circle and then lower it. Do this with your eyes open and then with your eyes closed.

Control of Internal Balance

In general you have been studying the part of the control system that *senses* the external environment. Now consider the responses to the internal environment that must take place within an organism in order for it to maintain the internal balance necessary for life.

The cells of all organisms need a watery environment; yet some organisms can live in the desert. The only way this is possible is for a desert-adapted plant or animal to preserve a watery environment within itself. It has to have a waterproof covering. Without such a covering it would lose water faster than the water could be replaced. This would cause the cells to dry out and die.

The bark of plants and the waxy coverings of leaves are waterproof. Some animals have scales and skin that are waterproof. An animal without such a waterproof covering must stay in or near water. Frogs and salamanders are examples of animals that *do not* have waterproof skin. A frog must keep its skin moist or it will soon lose so much water that it will die. How might this affect the distribution of frogs and salamanders in the biosphere?

Remember that water will diffuse across a membrane from an area of high concentration to an area of low concentration. Thus, if the concentration of water is greater outside a cell than inside, there is a tendency for water to enter the cell. Eventually such a cell will burst unless there is some way of regulating its water balance. The cell may require energy to *remove* water. On the other hand, if there is too little water outside a cell, the cell shrinks. Energy may also be required if a cell is to *retain* water.

In multicellular animals the cells are bathed by a fluid. In this fluid are all the raw materials the cells need for life. Also, the waste materials produced by the cells are released into this fluid, to be carried away. As long as the balance between what is inside the cells and what is outside the cells is maintained, the cells function efficiently. When the balance is seriously disturbed, the organism concerned becomes ill and may die. Multicellular organisms have developed very efficient—and sometimes complicated—methods of controlling internal balance.

In humans, for example, when the water level in the fluid surrounding cells falls too low, extra water will diffuse out of the capillaries into the cells. Sensors can detect the resulting lowered water level in the bloodstream. The thirst reaction is one response to such a lowered water level.

There is another response to a lowered water level in the bloodstream. In the kidneys, blood is filtered and some water is removed. The amount of water being removed can be regulated. When the water level in the blood is too high, great amounts of water are removed by the kidneys. When the water level in the blood is too low, much less water is removed by the kidneys.

A change in the amount of sugar in an animal's body is one factor involved in producing the feeling of hunger. When cells work, sugar is consumed. As a result, sugar diffuses from the capillaries into the fluid around the cells and then into the cells. As the blood-sugar level decreases, sensors in the brain detect the change. Food stored in the liver is changed to sugar by enzymes. The sugar then diffuses into the bloodstream. As the amount of sugar stored in the liver is lowered, hunger is felt. A meal may replace the used-up food, just as a drink of water helps maintain water balance. One result of what happens when the sugar-balance mechanism doesn't work properly is the disease called diabetes.

Excretion—Waste Removal from Cells

In order for an organism to maintain its internal balance, certain substances must be removed from as well as taken into cells. Carbon dioxide and nitrogen-containing wastes are examples of substances that may become harmful to cells if they are not removed. The removal of such substances is called *excretion.*

NOTE: *You should understand the meaning of three words before reading further. They are "excretion," "secretion," and "elimination." Cellular wastes are* excreted *from the cells and eventually the body. Substances produced by cells and organs which are directly or indirectly useful to an organism are* secreted. *The word* elimination *generally applies*

to wastes in the digestive tract that have never been used by cells and are eventually discharged through the anus (see Figure 3 • 23).

Carbon dioxide is excreted from cells into the bloodstream. Eventually it is carried to capillaries surrounding small air sacs of the lungs. CO_2 then diffuses through capillary walls and through the air-sac membranes into the lungs. In the normal process of exhaling, CO_2 is then eliminated from the lungs. At the same time, oxygen diffuses from the lungs through air-sac membranes and capillary walls into the bloodstream. It is then carried to cells throughout the body.

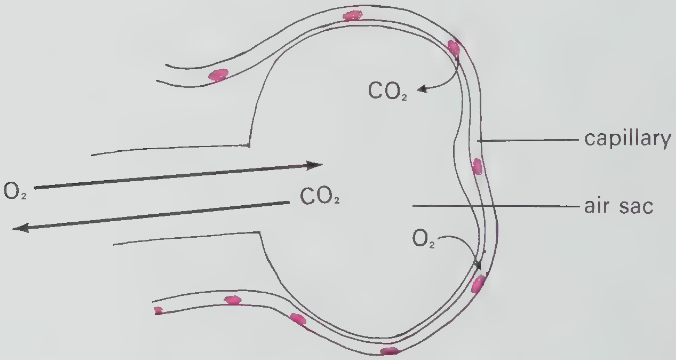


Figure 6 • 10. Diagram showing exchange of gases between capillary and air sac.

One problem you will meet in studying biology is that there are usually exceptions to every rule. Though CO_2 is normally considered a waste, it is also vital to the individual. There is an area in the brain called the breathing center. The breathing center senses the amount of CO_2 in the blood. If there is too much, it sends messages to the muscles and the rate of breathing increases. This lowers the amount of CO_2 in the blood. The breathing center then reacts by slowing the rate of breathing. In this case, CO_2 must be considered as being necessary to normal body functions rather than as being a waste.

Air pollution and cigarette smoking may cause a lung disease called emphysema. Lung tissue is damaged in emphysema, and

this damage restricts the movement of oxygen into and out of the lungs' air sacs (breathing). Carbon monoxide, a gas given off in the exhaust fumes from automobiles and gas heaters, is another substance that can indirectly interfere with breathing. Carbon monoxide will replace oxygen in the bloodstream. If enough carbon monoxide enters the lungs, the resulting lack of oxygen will soon cause death. It is for this reason that we must vent gas heaters and make sure that automobile exhaust fumes do not enter our cars. It is sensible to leave one or more side windows slightly open while driving or riding in a car. (The rear window of a station wagon should not be opened for ventilation.) Even if these precautions are observed, though, carbon monoxide and other toxic materials emitted from burning fuel enter the atmosphere, and thus the biosphere.

Figure 6 • 11. Two views of Los Angeles. Some authorities say that when the air looks as it does in the right-hand view, breathing it is similar to smoking two packs of cigarettes a day.

The removal of carbon dioxide is just one example of excretion. Another is the removal from the body of substances that contain nitrogen. Breakdown of protein in cells produces nitrogen-

containing wastes. These wastes are normally changed to urea and excreted into the bloodstream. Urea is removed from the bloodstream by the kidneys. From the kidneys it is transferred through tubes to the bladder, where it is stored (with water) as urine until it is discharged. The functioning of the kidneys and lungs helps to maintain a normal internal balance.

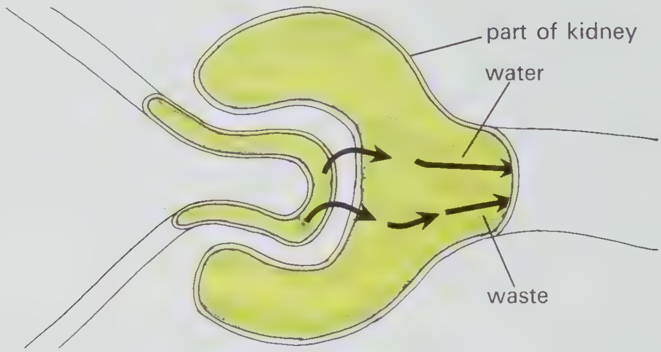


Figure 6 • 12. A simplified diagram of a part of a kidney. Some wastes are transferred with water from the capillaries into tiny structures in the kidney.

Coordination and Glands

There are many ways in which organisms respond to changes in their environment, regulate their lives, and maintain a favorable internal balance. A snake or a lizard will move into and out of the sun, thus regulating its temperature. A mammal, on the other hand, has a temperature-control system that regulates the diameter of small arteries near the surface of its body. In a warm environment these arteries dilate, allowing a comparatively large volume of blood to flow near the body surface, where heat may be given off.

Organisms have other kinds of control systems, too. For example, they may run faster, jump farther, and defend themselves more fiercely at times of sudden crisis than they could under normal conditions. This added strength and bodily coordination may come about when an organism is suddenly frightened or challenged by something dangerous to it.

These are examples of coordination of activities in the body in times of need. They are possible because of the interaction of

two very important systems of the body, the nervous system and the *endocrine gland* system. These two systems function together as a means of communication between the different parts of an organism and between the organism and the outside world.

Some of your earlier investigations dealt with control by the nervous system. You studied the results of simple stimuli and responses to them. In each case, its response enabled the organism to adjust to a change. Now you will study the relationship between the nervous system and the endocrine system.

Glandular Control

What happens if someone shows you a lemon and asks you to imagine you can taste it? Do you notice more saliva in your mouth? The sight of a lemon causes a message to be sent through a sensory nerve to the brain. The "switchboard" of the brain sends a message through a motor nerve to the salivary glands, causing the glands to secrete more saliva.

The salivary glands and other glands that secrete moisture (tears, sweat, for example) empty their secretions into ducts. But there are also glands that do not have ducts. They are called ductless glands, or endocrine glands.

Endocrine Gland System

Endocrine glands, such as the pituitary, adrenal, and thyroid, secrete substances directly into the bloodstream. The secretions are called *hormones*. In the bloodstream the hormones can be carried to all parts of the body. Small amounts can have a great effect on the body. Endocrine glands may be stimulated to activity by one another. They may also be stimulated by nervous impulses.

An adrenal gland is attached to the top of each of the kidneys. One part of these glands produces a hormone, adrenaline. It can speed up the heartbeat. Remember how you have felt when you were very frightened or before an important game or a public performance. Didn't you get "butterflies"? Adrenaline had closed the small arteries leading to the capillaries around your stomach and intestines (hence the "butterflies"). At the same time, it had

opened up circulation to your muscles, making them capable of stronger, more prolonged contraction.

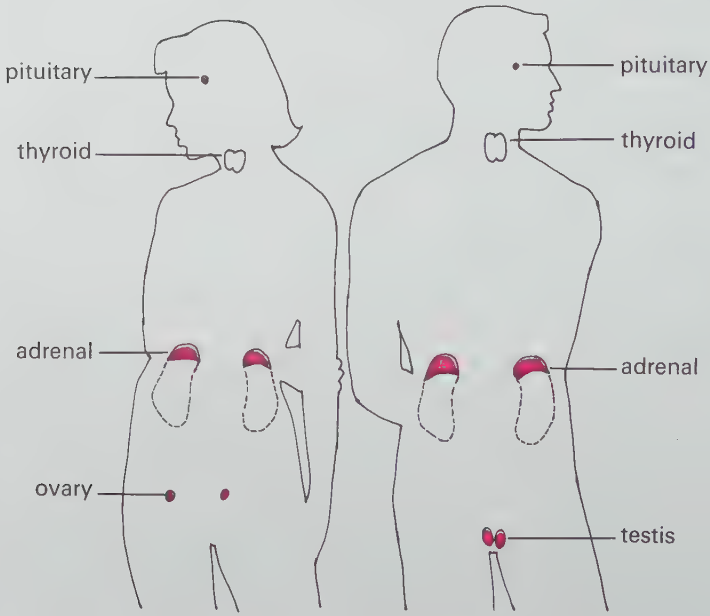
Another characteristic of adrenaline is its ability to speed up the action of the liver, making sugar available to the bloodstream. Why would this be of value in an emergency?

The thyroid gland secretes hormones that regulate growth and influence the way the body uses energy. Sometimes a shortage of the thyroid hormone in a person's body makes him lazy and overweight. If too much thyroid hormone is produced, a person may be overactive and lose weight.

The reproductive glands (testes and ovaries) secrete hormones that are important in developing several differences between males and females. The bright color of a male bird, the antlers on a male deer, and the generally low-pitched voices of adult human males are a few examples of differences caused by reproductive hormones.

The pituitary gland and other nearby areas of the brain control the endocrine glands and have an effect on many functions of the body. Because it controls so many things, it is often called the

Figure 6 • 13. A diagram showing the location of endocrine glands.



master gland. The nearby area of the brain is even involved in some kinds of behavior. When it is not functioning properly, the health of an individual may be affected.

Upsetting the Balance

Internal balance may be disrupted by either disease organisms or stress caused by constant stimulation of the nervous system. A little stress is good; too much is not.

Stress can be caused by inadequate food, not enough sleep, too much noise and confusion, or difficult problems that the individual cannot solve. Some people can work in the midst of confusion and seem to ignore it. Others get quite upset if music, talking, or TV is too loud and continuous.

Stimuli originating from stress-producing conditions, no matter where they are received, go directly to the brain. The brain and/or the pituitary gland either directly or indirectly cause increased or decreased activity of the endocrine glands.

Stress, because it overstimulates the nervous system, can indirectly upset endocrine balance. Most stress results in nervousness or anxiety. Since these conditions are assumed to be related to the mind, ill health caused by some forms of stress can be called mental ill health. To keep good mental and physical health, then, it is important to recognize stress and, if possible, to decrease activities that may lead to it.

Artificial stimulation of the pituitary area of the brain may cause an animal to find food and eat even though it has just had a meal. This is one example of an upset of internal balance. Because its balance is upset, the animal may become physically ill.

Extending Your Knowledge

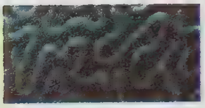
Your body is composed of many parts. Each part is specialized in a definite way for keeping you alive and healthy. Your digestive system changes food into substances that the cells of your body can use. Your kidneys remove some waste products. Muscles make it possible for you to breathe, speak, and move. Your eyes, ears, and nose tell you much about the surrounding world. Your lungs take in oxygen from the air and eliminate carbon dioxide. Both your nerves and your endocrine glands coordinate many separate activities.

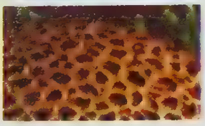
We know that there must be a high degree of balance between cells and the internal and external environments or we may become ill—even die. We also know that we are completely dependent upon the biosphere for everything that makes this balance possible. For example, suppose that chemists produced some kind of chemical poison (like DDT) and that, through reckless use, enough of it was released into both the atmosphere and the oceans to pollute them. How might this interfere with the internal balance of humans?

Try to answer this question on the basis of what you have studied in this course and of your own ideas. Try to express *your* ideas and opinions, and facts as *you* see them—in *your* own words.

SECTION SEVEN

Organisms in the Biosphere





When people first began to communicate, they gave names to the organisms they found around them. They probably did so for many reasons. Some of the plants were poisonous—others were safe to eat. Primitive people were afraid of some animals, and rightly so. Without giving names of some kind to the plants and animals, they could not talk about which plants were edible or which animals should be feared. All this information was probably passed on to young children—generation after generation.

Even today people are interested in knowing the names of different organisms. Do you remember your observations with the mini-biosphere? Someone probably saw an organism in the mixture and asked: What is *that* thing? You may have wondered how you find the name of the unknown organism. Perhaps you were able to find names for some of the organisms you saw. When you did find a name, it may have sounded strange, and probably you wondered why the organism to which it applied has such a peculiar name. Perhaps you found an organism that has not even been named. If so, how would it be named?

The number of different kinds of organisms in the entire biosphere is staggering. Biologists have already named about one and a half million different kinds. But they are the first to admit that they have not discovered all the kinds that exist. Many thousands of new ones are studied and named each year.

Naming Organisms

About 140 John Smiths are listed in the Philadelphia, Pennsylvania, telephone directory. The men in that directory with the *first name* of John number into the thousands. "John Smith" and "John" are obviously very common names. If I asked you to call my friend John Smith—or worse, my friend John—in Philadelphia and say hello for me, you would have a busy time even if successful. You might call a lot of numbers and never reach my friend.

In two years of research, a biologist found 139 different kinds of spiders along the North Carolina coast. In his published report on these organisms, he could have simply called each of them "spider," saying "this spider" occurred under bushes and "that spider" occurred in marshes. But this would be about as helpful as naming everybody in Philadelphia "John." Another possibility would be for the biologist to lump all the spiders together by color and call each black one "black spider," each gray one "gray spider," and so on, somewhat like calling many people "John Smith" and "Joe Smith." This would be a little more helpful if you wanted to sort out the different spiders—but not much. Wouldn't it be more valuable to give a "special name" to each of the 139 different kinds of spiders, so you could tell them apart? How would you do it?

You might make up a name for each North Carolina spider, something more specific than "black spider" or "gray spider." For example, there could be the "hairy-legged spider," the "milky-eyed spider," the "humpbacked spider," the "long-legged spider," "Whitman's spider." But if you lived in the East and wanted someone in California to know what you were talking about, you would have to make up different "common names" for *all* the spiders in the United States. To describe a spider exactly, you might end up by calling it something like "the large humpbacked

Figure 7 • 1. In Germany this animal may be called *die Küchenschabe,* a Frenchman might call it *une blatte* or *un cafard,* and a Japanese knows it as 油蟲

Americans call it a cockroach.

spider that has yellow stripes on its back and builds its circular web in oak bushes along the South Atlantic coast of the United States."

One thing wrong with common names is that they frequently give us incorrect impressions about the organisms to which they refer. Ladybugs are not bugs at all—they are beetles. Horned toads are lizards. And poison ivy is not even closely related to the ivy vine.

Of course, the common name of an organism in English is generally not its common name in any other language. Unless you are up on your Dutch, you might not realize that a *wilde eend* is a mallard duck, and it would be hard to guess that a *gräsparv* is, in Swedish, an English sparrow. In Spain and Mexico a cockroach is called a *cucaracha*. Can you imagine what the common name for "cockroach" would be in Japanese? (See Figure 7 • 1.)

But, perhaps worst of all, some common names are applied to several different organisms. In England, for example, the robin is a very different bird from the robin we know in the United States. The cottontail rabbit in England is not the same kind of cottontail rabbit we have in the United States. In Wyoming the gopher is a rodent that burrows under the ground. In Minnesota the so-called gopher is actually a thirteen-lined ground squirrel. In Florida the name "gopher" refers to a land turtle. Students at the University of Minnesota call themselves the "Golden Gophers." They would be more accurate if they called themselves the "Golden Thirteen-lined Ground Squirrels."

How can these difficulties be avoided? Many years ago, before 1700, biologists developed the idea of using a descriptive passage written in Latin for each animal and plant known in the world. (Of course, there were not so many known then as now.) Imagine calling the Jerusalem cherry (which is neither a cherry nor from Jerusalem, but is a shrubby relative of the potato) *"Solanum arborescens nuper inter peregrinas allata est"!* In today's biological shorthand it is simply *Solanum pseudocapsicum.*

Every animal and plant now has two special names. That is the way the North Carolina biologist we were talking about earlier named the 139 spiders. Some of these names have been in-

Figure 7 • 2. Each of these animals is called a gopher by people who live in different parts of the country. How do Figures 7 • 1 and 7 • 2 illustrate two of the difficulties involved in the use of common names?

Figure 7 • 3. Scientific names of some of the 139 North Carolina spiders.

Allotheridion australe	*Lycosa modesta*
Allotheridion chinda	*Pardosa floridana*
Allotheridion dividuum	*Pirata apalacheus*
Allotheridion lyricum	*Phidippus whitmanii*
Atypus bicolor	*Tapinopa bilineata*
Lycosa annexa	*Teudia fragilis*
Lycosa carrana	*Trochosa shenandoa*
Lycosa lenta	*Zelotes hentzi*

Figure 7 • 4. A Red-headed woodpecker (*Melanerpes erythrocephalus*).

cluded in Figure 7 • 3, and you will notice that no two in the list are exactly alike. Each one of the 139 spiders has its own name.

The North Carolina spider names probably look to you as if they were written in a foreign language. And indeed they are. But it is a language which is unfamiliar to nearly everyone alive in the world today. These names come from Latin and ancient Greek.

The first word in a scientific name is called a generic name and is always capitalized. The second word is a specific name and today is generally not capitalized. A generic name followed by a specific name makes up an organism's scientific name. Very closely related organisms have the same generic name but different specific names—just as two brothers named "Smith" may be John and Norman. Our North Carolina biologist knows that all of the *Lycosa* are related, and he can say that he found at least four different kinds of *Lycosa* in North Carolina.

In scientific names the generic words are nouns that often say what organisms are. Sometimes a generic name is just the Latin or Greek common name of the organism concerned. Specific names are often descriptive. A good example would be that used for the Red-headed woodpecker, *erythrocephalus*. *Erythro-* means "red," and *-cephalus* means "head." You may already be familiar with the word "erythrocyte," which means "red cell" (red blood cell). The generic name of the Red-headed woodpecker is also descriptive: *Melanerpes*, which means "black creeper." Long ago we might have called this bird, in Latin, "the black bird with the red head which creeps up trees." Today it is called "*Melanerpes erythrocephalus*." The scientific name is used for the Red-headed

woodpecker by scientists wherever in the world it is discussed or seen or written about, and no other bird has this particular scientific name.

This system about which we are talking—giving a name consisting of two words to every organism—was first popularized in the mid-1700's by the Swedish naturalist Carolus Linnaeus, a professor at the University of Upsala. His ambition was to name all

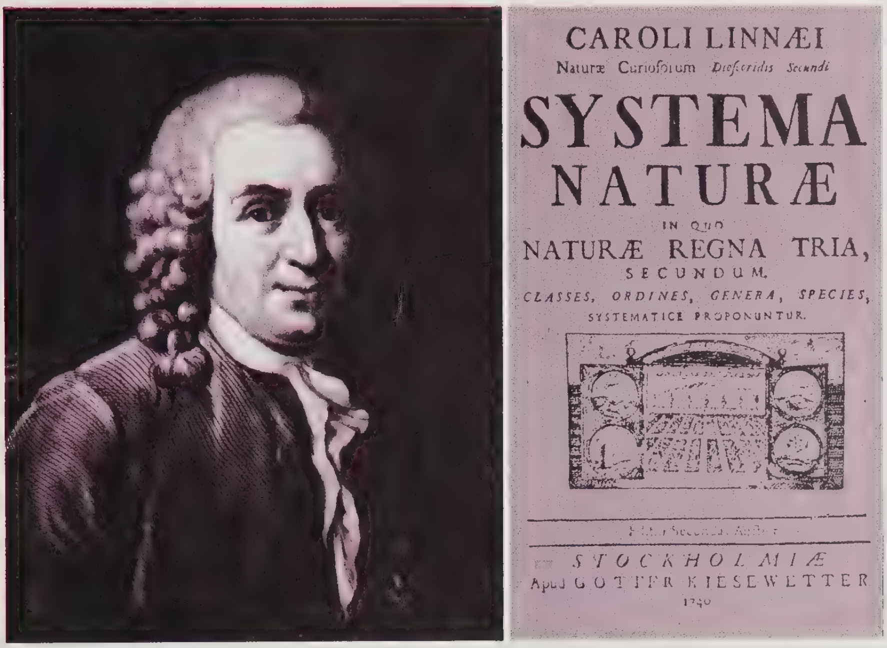


Figure 7 • 5. Carolus Linnaeus published some results of his work in 1740.

the organisms in the world. He asked friends to collect them for him, and he sent students all over the world. Many of these Linnaean collectors had wild adventures, and some even lost their lives in strange and distant countries. But enough specimens or descriptions were brought back to Sweden so that Linnaeus was able to name about 7700 plants and 4400 animals. Many of his original names are still in use.

INVESTIGATION 7.1: Names and What They Mean

Imagine yourself as a scientist who has collected the 15 organisms pictured in Figure 7 • 8. The people of the area you collected in have furnished you with common names for the organisms. Your task is to make up descriptive scientific names for these organisms. Some of your answers may be just the generic names and some just the specific.

PROCEDURES

A. Study the descriptive Latin or Greek terms (Figure 7 • 6). These are words that can be used to name organisms. You may combine words to describe an organism.

B. Study the drawings and common names in Figure 7 • 8. Look through the list in Figure 7 • 6 again for descriptive terms.

For example: Look at the picture of the giant panda (Figure 7 • 7). It is black and white. Search the list for the words "black" and "white" ("black" = *melano;* "white" = *leuco*). If you put these words together, *melanoleuco*, you have a description of a black-and-white animal—and that *is almost* the specific name given to the giant panda by scientists. They call it *melanoleuca.*

C. Using the Latin or Greek words listed in Figure 7 • 6, construct either a generic or a specific name for each of the organisms illustrated in Figure 7 • 8. Discuss with other students and with your teacher the names you have chosen. Did all the students in your class suggest the same names?

Figure 7 • 6.

Vocabulary			
bates	= climber	*lineatus*	= lined
bi	= two	*melano*	= black
campus	= sea monster	*myrmeco*	= ant
cephalus	= head	*nocti*	= at night
cordi	= heart-shaped	*octo*	= eight
cornis	= horn	*petala*	= petal
curvi	= curved or bent	*phaga*	= eat
dentata	= toothed (plant leaf)	*platy*	= flat
domesticus	= found around house	*punctata*	= dotted
folium	= leaf (*folia* = plural)	*rhino*	= nose
hippo	= horse	*rostra*	= beak or bill (bird)
hylo	= tree		
leuco	= white	*sex*	= six
vagens	= travel or wander	*tri*	= three

Figure 7 • 7. Giant panda.


hog-nosed snake
heartleaf arnica
anteater
red crossbill
two-spotted ladybird beetle

Figure 7 • 8.

common housefly

silver-haired bat

sagebrush

bald eagle

sea horse

Figure 7 • 8.
(*cont.*)

INVESTIGATION 7.2: Inventing a Classification System

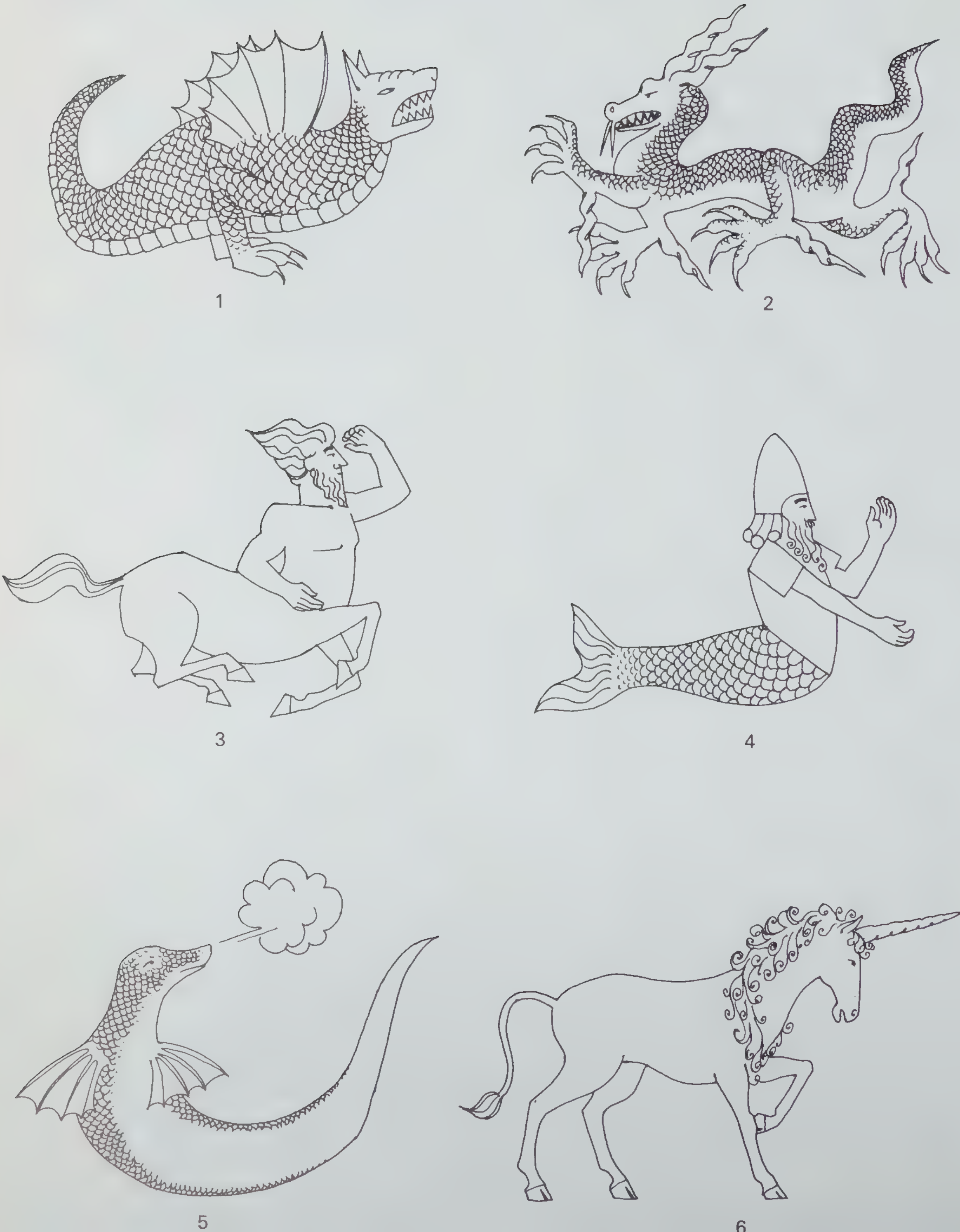
When you are studying many different kinds of things, it is often useful to try to arrange them in some kind of order. Imagine that you were in a huge library and found that all the books were just placed on the shelves at random. How would you find a book on history, or baseball, or painting? You would probably spend many hours looking for the particular book you wanted. Wouldn't the library be much more useful if the books were first classified—arranged in groups of similar subjects (such as history, baseball, and so on) and all books in the same group placed on shelves in one area? You should then have little trouble finding your book. Libraries do classify their books.

Biologists likewise place similar organisms in the same group. That is, they classify them. Biological classification is based upon evolutionary relationships—upon characteristics shared by different organisms and inherited from the same (common) distant ancestors.

The thirteen organisms in Figure 7 • 9 are all make-believe, having appeared in myths and other accounts in the past. However, even though they are mythical, they probably look no stranger than some real organisms that have been discovered.

Like a biologist who is classifying real animals, you will have to decide what will be the basis for your various methods of grouping together these mythical animals. You may want to group together all those that look like horses, or have hair, or have wings. One of your groupings might include three organisms, another only two, and so on (that is, perhaps only three of the thirteen organisms would share the particular characteristic that determines your grouping, whatever that characteristic happens to be). Or you may wish to use a variety of different characteristics and groupings. Certainly, different students in your class will choose different characteristics for their groupings. When you have had a chance to use your scientific imaginations and set up your groupings (classifications), it should prove interesting to have a class discussion about advantages of the different methods of grouping.

Figure 7 • 9.



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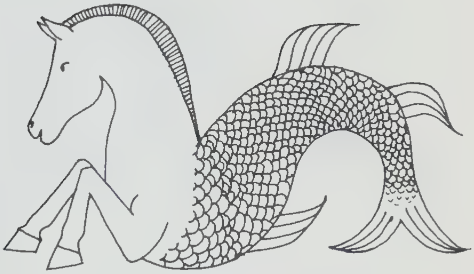

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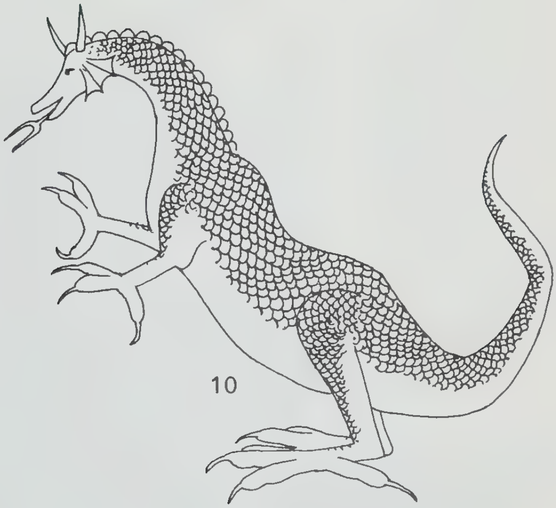

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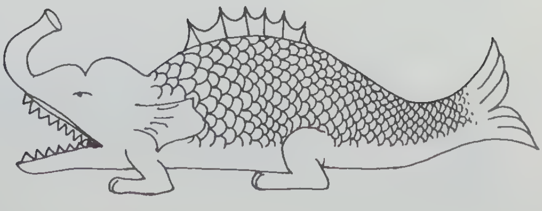
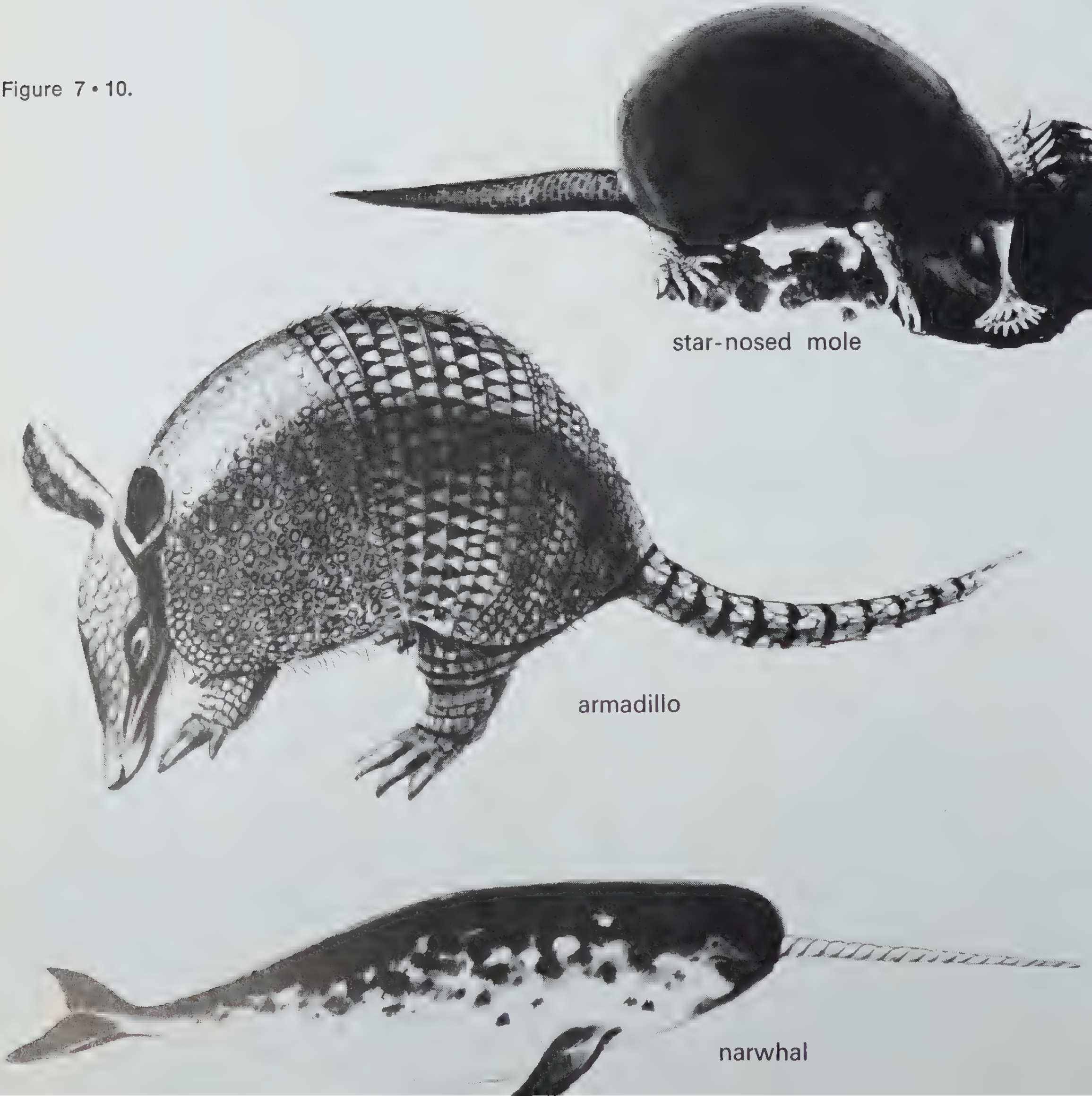


13

Now look at the three animals in Figure 7 • 10. These are somewhat unusual-looking. But as you may have guessed, they differ from those in Figure 7 • 9 in that they actually exist now. In fact, although it may be difficult for you to believe, they have all been classified by biologists as mammals. Classifying organisms, therefore, must involve more than just grouping together organisms that look alike and putting in another group organisms that appear different!

Where would you place these three animals in your classification system?

Figure 7 • 10.



Methods of Classification

You classified or arranged the imaginary organisms in Investigation 7.2 entirely according to their external appearance. In the classification of real things in the biosphere, some of the earliest systems were very much like this. By the time the American colonies were becoming established, Linnaeus and other biologists were developing more complicated systems of classification. Classification means arranging organisms into groups, which we still use today. Individuals that seem to be alike in all important ways are put into the same *species*. Individuals of the same species are

A B

C D

Figure 7 • 11. How would you classify each of these—animal or plant?

so alike they can breed with each other and produce normal offspring. Closely similar species are put in the same genus. Similar genera (plural of "genus") are grouped into a *family*. Similar families are placed in still other groups.

One way to help you understand how a biologist classifies living things is to compare classification of an organism with the way books may be grouped in a library. For example, we might compare the biologist's classification of a common pet—the dog—with a librarian's classification of books about dogs.

Biologist's groups	*Librarian's groups*
Kingdom—Animalia (animals)	Nonfiction books that contain factual information
Phylum—Chordata (animals with a backbone)	Science—factual books about nature
Class—Mammalia (animals that nurse their young)	Biology—books about living things
Order—Carnivora (animals that eat other animals)	Zoology—books about animals
Family—Canidae	Pets
Genus—Canis	Dogs

Your dog's scientific name would be *Canis familiaris.*

The important thing to remember about biological classification is that it is based upon what biologists know and think about the relationships among organisms. A dog doesn't know that it is a dog or that it is supposed to be so closely related to coyotes, wolves, and foxes that they are all placed in the same family (Canidae). Biologists recognize that these mammals are related because they all have certain characteristics in common.

Take another look at the three organisms in Figure 7 • 10. They may not look like members of the class Mammalia (mammals), but biologists are convinced that they are. They all have the following characteristics: mammary glands to nourish their

young, red blood cells without nuclei, and hair.

It is not always easy to identify organisms. The difference between two species of mice, for example, may be very slight. The difference may be in the length of their tails and hind feet or in the structure of their teeth. Two families of beetles may be separated according to whether they have five segments or six in the abdomen. Non-biologists like to identify things by referring to pictures, but you have already found that often appearance is not very helpful for identification. Biologists, consequently, use what are known as identification keys.

Identification keys are usually made up so that as you read them, you encounter two choices for each characteristic listed. There could be a key to evergreen-tree genera where you would have to decide whether a tree has needles wrapped in bundles or not wrapped in bundles. Pine trees, for example, have needles in bundles, whereas spruce and fir trees do not. Or two genera of pocket gophers might be separated according to whether or not they have grooves in their front teeth ("incisors grooved or not grooved").

Figure 7 • 12. An example of a varying characteristic in evergreen trees.

Figure 7 • 13. What characteristics would you pick as a basis for identifying these jays?

INVESTIGATION 7.3: Using a Simple Key

Figure 7 • 14 shows you one type of identification key. It is based on the characteristics of the plants and animals you named in Investigation 7.1. Each numbered choice in the key is based on certain identifying characteristics. Study Figure 7 • 14. Notice that there is a series of numbered choices on the left side. On the right side are either numbers or names of organisms. Begin with Choice 1. Notice that you will have to choose between 1a and 1b. Now continue down the series. If the choice of characteristics in the body of the key leads to a number, such as 5, you must skip down to 5a or 5b. When the choice leads to a name instead of a number, you have found the name of the organism you are identifying.

For example: If the organism you are trying to identify has a stem and leaves (Choice 1a), you can see by the key that you must go to 2. From 2a or 2b you will be directed to 3 or 4. Choice a or b under 3 or a or b under 4 gives the name of the organism. At each step you must make an either/or judgment about the identifying characteristic given for each number. Select an organism pictured in Figure 7 • 8 and find the name of that organism by using the key. Continue using the key to find the names of the other 14 organisms.

ON YOUR OWN: Designing Your Own Key

Now that you are familiar with using keys, try making one of your own—for *real* organisms. Bring to class a variety of different plants and animals (insects, small plants, and the like) or parts of different plants—small branches or leaves from different kinds of trees or shrubs.

Make a key, based on differences that you can observe, for identifying what you have collected. You need not use the same

Identification Key		
Choice	Characteristic	Go to
1a.	Leaves and stems present	2
1b.	Leaves and stems not present	5
2a.	Leaves at base of stem; flowers present	3
2b.	Leaves all along stem; no flowers present	4
3a.	Leaves large and heart-shaped; flowers have nine petals	heartleaf arnica
3b.	Leaves small, not heart-shaped; flowers have eight petals	mountain dryad
4a.	Leaves long and narrow, with three teeth at end	sagebrush
4b.	Leaves broad and heart-shaped	clover
5a.	With six legs	6
5b.	With fewer than six legs	7
6a.	With two spots on its back	two-spotted ladybird beetle
6b.	With two wings	common housefly
7a.	With wings	8
7b.	Without wings	10
8a.	Wings with feathers	9
8b.	Wings without feathers	silver-haired bat
9a.	Bill not crossed	bald eagle
9b.	Bill crossed	red crossbill
10a.	Without legs	11
10b.	With legs	12
11a.	Body short, with definite ridges and fins	sea horse
11b.	Body long and smooth; no fins	hog-nosed snake
12a.	Body with a long tail	13
12b.	Body without a long tail	14
13a.	Without hair; short nose; six lines on body	six-lined race runner
13b.	With hair; long nose; without six lines on body	anteater
14a.	Four legs; nose with horn; not found in trees	rhinoceros
14b.	Two legs; nose without horn; frequently found in trees	gibbon

Figure 7 • 14.

kind of key used in Investigation 7.3. Try designing different kinds of keys for identifying your material. The real test of a good key is whether or not someone else can use it. Exchange your key and materials with other students. If others in your class can follow your key and correctly identify your materials, you have succeeded. If they cannot do so, redesign your key until it *will* work for others.

Extending Your Knowledge

Figure 7 • 15. Two views of a rosebud. What is happening here? How could a gardener use this information?

SECTION EIGHT

Ecological Interactions

Many species of organisms are in danger of becoming extinct. Their future—indeed, the well-being of all the species in the biosphere—may be in jeopardy if we fail to learn more about the interactions that exist in the biosphere. These interactions may involve members of a single species. They may also be interactions among different kinds of organisms and between organisms and their physical environment. The study of these interactions is called *ecology*.

Members of a Population

Look about your classroom. You may see many different types of human beings—tall and short, dark and light, blond and brunet, and so on. It would be difficult to give a complete description of the class. But two general statements can be made about the entire group at any one time. First, a number of students and teachers are present (make a count). Second, they all belong to the species *Homo sapiens*. By saying these two things, you have briefly described the human *population* of the room.

Until now you may have thought of populations as being made up only of human beings. (Indeed, the word "population" comes from the Latin word meaning "people.") But there are also populations of other animals and of plants. All the organisms of one kind found in an area make up a population.

Most parts of the earth's surface are inhabited by a very large number of different populations. Take your town or city, for example. There is a human population. There is also a population of dogs, one of cats, and perhaps one of dandelions.

It is often difficult to find out what *kinds* of organisms exist in an area, but sometimes it is even more difficult to find out the sizes of the various populations. The United States takes a census of its citizens every ten years (most recently, in 1970); this is a fairly accurate count. When taking roll, your teacher is making a population count—and it is usually accurate. But just try count-

ing all the ants on the baseball field or all the grass plants in a lawn. Biologists have thought of some ways to estimate the sizes of such populations.

INVESTIGATION 8.1: How Many Beans?

During this investigation, you will estimate the number of beans in a paper cup. In doing so, you will learn one method used by scientists to estimate the number of individuals in a natural population—for example, fish in a lake, ants in an anthill, or mice in a field.

MATERIALS

Paper cup filled with white beans

Red beans, 10

PROCEDURES

A. Try to plan two or three methods for estimating the number of beans without counting all of them. Write brief descriptions of the methods and number them in your data book. Use each one to make an estimate, and record the results in a chart similar to Figure 8 • 1.

	Procedure A (your methods)			Procedure B (population-census method)	Procedure C (actual count)
	1	2	3		
Number of beans					

Figure 8 • 1.

B. A *population-census method* is used by ecologists who must estimate sizes of populations. In using this method, they introduce some marked individuals into a population. They assume that the marked animals will mix with the animals already there. For example: Ten marked deer are added to a herd of 90 unmarked deer. Then deer from the mixed herd are ran-

domly caught. And about 1 out of every 10 of these should be a marked deer. Applying this method here, you would add 10 red beans to the cup of white beans. Then you would make sure that the beans are *well mixed.* A sample of beans should contain about the same ratio of red beans/white beans that the whole cup of beans has. Suppose a sample of 20 beans taken from the cup contains 2 red ones and 18 white ones. Here the ratio is 2/18. You already know that there are 10 red beans in the cup. From this information you can set up an equation:

$$\frac{2 \text{ red}}{18 \text{ white}} = \frac{10 \text{ red}}{X \text{ white}}$$

X stands for the total number of white beans. By solving the equation (finding the value of X), you will learn, without having to count them, that the cup contains about 90 white beans.

$$2\,X = 180\ (10 \times 18)$$

$$X = \frac{180}{2} = 90 \text{ (white beans)}$$

Try this method and enter the results in your chart.

This is another method you could use. Your sample contained 2 red to 18 white beans. That means there are 9 times as many white beans as red ones. You know there were 10 red beans; therefore, $10 \times 9 = 90$ white beans.

C. Count the white beans one by one. Compare the count with your various estimates.

ANALYSIS

Which method of estimating did you find most accurate?

Changing and Stable Populations

At the beginning of this section, you recorded the population of human beings in your classroom. Look at the record of the population for that day and compare it with the classroom population today. Chances are that the number of *Homo sapiens* in the classroom today is slightly more or less than it was before. But even if the number is the same, the roll call may be different. Some students may have moved into or out of the school district; someone who was in class last time may be home today; someone who was in the counselor's office may now be back in class.

Sometimes populations do remain the same—hour after hour, day after day, even year after year. But more often they change. They may increase or they may decrease. In your town or city, for example, births will increase the population. Deaths will decrease it. (Check the birth and death notices in your daily newspaper.) Also, people moving into or out of the community will increase or decrease the population. Thus, three things affect the size of the human population for any particular area: births, deaths, and movement of people into and out of an area (*dispersal*). These things affect population size for other kinds of animals as well. If a population is not changing in size, it is said to be in balance. This happens when births, deaths, and dispersal balance one another.

In terms of providing enough space, food, shelter, and so on, any particular area can support only a certain number of individuals of a kind. This is known as its *carrying capacity*. Consider again the number of people in your classroom population. How does it compare with the number of desks? If there are unoccupied desks, then the room's carrying capacity for students has not been reached. There is probably room for all of you to sit, to move around, to use books and equipment. But if your school has to go on "split sessions" because of the number of students enrolled, then you will understand how the carrying capacity can be exceeded.

A school bus has a certain carrying capacity for students, and an elevator can carry only so many passengers. A pasture has a

limited carrying capacity for cattle—based largely on the amount of grass available for food. If you find a badly overgrazed pasture, then you can guess that the carrying capacity of the pasture has been exceeded. If hay is thrown into the pasture, then the carrying capacity for cattle has been increased for a short time. But if the cattle increase in number, they may eventually run out of space even if they have plenty of food.

It is easy to see how the carrying capacity of an aquarium could be exceeded. Indeed, you may be able to see this in your classroom. A 5-gal (19-liter) aquarium will support only a limited number of goldfish. There is a rule of thumb that states: 1 gal (3.78 liters) of water in an unfiltered aquarium is necessary to support 3 cm of fish. This means that in a 5-gal aquarium you should have no more than one 15-cm fish or five 3-cm fish. The carrying capacity for fish depends not only upon available food but also upon the amount of oxygen and carbon dioxide in the water. Buildup of wastes may be another factor that affects the carrying capacity of an aquarium.

If a 5-gal aquarium has a limited carrying capacity for fish, is this also true of a large lake? Some fishermen like to have the state fish-and-game department stock lakes with as many fish as possible. But if a lake has a carrying capacity for only a thousand

Figure 8 • 2. The population of sheep has exceeded the carrying capacity of this land.

30-cm fish, what do you think might happen if ten thousand 30-cm fish were introduced into the lake?

It is easy to form the habit of thinking about populations only in terms of numbers of organisms: 1000 fish in a lake, 30 persons in a classroom, and so forth. But populations can be measured in other and sometimes more useful ways. For example, a population can be measured in terms of the total weight of all the organisms in it. This total is the weight of the population (called *biomass* by ecologists). It is one thing to say that there are 27 cows and 27 mice in a pasture. The numbers of individuals are the same. But you get an entirely different picture of the cow and mouse populations when you say that the pasture contains about 16,400 kg (32,100 pounds) of cows and only 560 g (20 ounces) of mice.

Suppose a lake has a carrying capacity for 455 kg (1000 pounds) of fish. If a fish 30 cm long weighs 0.455 kg (1 pound), the lake could support a thousand fish of this size or many thousand 2-cm-long fish. Which would you prefer?

In addition to knowing the numbers and weight of a population, it is interesting to know how much *food energy* it possesses. For example, instead of counting or weighing all the grass plants in a square meter of grassland, you may want to calculate the food energy in the grass. This is more useful than numbers or weights if you are trying to determine how many cattle or bison (buffalo) a grassland will support. Cattle and bison depend upon the energy available from the grass, not the number or weight of the grass blades.

You may recall (from Section Five) the discussion of energy in food. This energy is measured in Calories. If a square meter of grass in one field contains 288 Calories and a square meter in another field of the same size contains 428 Calories, which field will support a larger number of cattle or bison?

Any population of organisms has a potential for increasing its numbers. This is called *biotic potential.* Our human "population explosion" is an example of the biotic potential of *Homo sapiens.* On the other hand, many things may keep a population from increasing. Such factors are known as the *environmental resistance.*

A high birthrate in a population of rats would tend to increase its size. A lack of food or space, environmental resistance, would tend to decrease it.

In nature, population sizes usually represent a balance between biotic potential and environmental resistance. In our interactions with the biosphere, we try to increase the environmental resistance against organisms we dislike and lower the resistance for organisms we like. We spray dandelions with herbicide to get rid of them (increasing environmental resistance), but we irrigate dry fields to improve growth of food crops (lowering environmental resistance).

FOR CLASS DISCUSSION

1. How might antibiotics provide environmental resistance?
2. In what way might use of a drug that controls a tropical disease affect the human population of an underdeveloped nation? How might it affect the population of the disease organisms?
3. How might you account for the periodic "population explosions" of small mammals such as mice and lemmings, or of insects?

INVESTIGATION 8.2: Environmental Resistance

A grass-water mixture includes several different populations of microorganisms. However, in this investigation all the microorganisms in each jar will be treated as a single population. What are some of the factors that you think would affect population growth among microscopic freshwater organisms?

MATERIALS

Pint jars, 5 (or more, as desired)
Chemicals and supplies (furnished by your teacher)
Grass-water mixture or pond water, 500 ml

PROCEDURES

A. Your teacher will provide your team with water from a grass-water mixture like the one you worked with in Investigation 1.1. Or you will begin with some water from a local pond or lake. Number the jars 1 to 5. Pour about 100 ml of the water into each jar.
B. Using a microscope, examine drops of water taken from each jar. Record your observations in a table like Figure 8 • 3.
C. To four of the jars add a material that you think might cause a population increase or decrease. Record the treatment for each jar in your data book, in a table like Figure 8 • 3.

Figure 8 • 3.

Jar	*Initial Observations*	*Material Added*	*Appearance after 1 Week*
1			
2			
3			
4			
5			

D. Do not add anything to the fifth jar.
E. Predict what you think will happen to the microorganism population in each of the five jars.

F. Examine the contents of the jars after about one week. If possible, use a microscope to examine drops taken from the jars. Record any differences among the five populations.

ANALYSIS

1. What is the purpose of Jar 5?
2. Was the environmental resistance lowered in any of the four experimental jars?
3. What, if anything, caused an increase in the environmental resistance?
4. Were you able to predict the observed results?
5. Did different species of organisms appear to be affected in the same way?

ON YOUR OWN: Limiting Factors

Various kinds of environmental pollution tend to increase environmental resistance to various organisms. When such a factor limits the size of a population, it is called a limiting factor. Too much of something or too little of something might serve as a limiting factor.

See if you can uncover any examples in your community of people's attempts to raise or lower environmental resistance to different organisms. You may be surprised at how many different—and perhaps unusual—examples you can turn up. They can be shared in a class discussion.

Interaction—Cooperation and Competition

In a basketball game, many interactions occur. The individuals on each team cooperate with one another. But the two teams compete with each other. Cooperation and competition are two of the kinds of interactions that occur among individuals and groups of organisms.

An understanding of interactions is an important part of the study of populations. No individual animal or plant can live entirely by itself. Every organism is involved in relationships with one or more other organisms and with the physical environment. Shrubs in a desert compete for water. Sharks compete for the flesh of dying prey. Wolves compete for leadership of their pack. Ants in a colony cooperate in constructing an anthill, in obtaining food, and in defense. Colonies of ants in two neighboring hills would have to compete with each other for food and space if each colony did not establish its own *territory* around each hill. The ants in each hill work, eat, and raise their young within a territory that they defend against invasion by ants of other hills.

Many kinds of animals establish territories within which they live and which they will defend against others of their species. Once territories are established, there seems to be less fighting among individuals or populations of the same species: each individual or population generally stays within its own territory. Thus time and energy can be used in gathering food and in other necessary activities.

Nations, states, and counties are examples of human territories. The human populations within them may cooperate or compete with one another. Think of some examples of such cooperation and competition.

INVESTIGATION 8.3: Interaction Among Harvester Ants

Harvester ants are large, brownish-red insects that are common on the western great plains. Their hills are made of dirt and small pebbles and are usually found in rather dry grasslands. Ants of each hill live within a specific territory extending around the hill. They feed within the territory and will defend it against any invading ants.

In this investigation, you are to prepare a map of a small area with anthills. Your map should be drawn to scale on a sheet of graph paper. The techniques you learn can also be used to study other territorial relationships, such as those of insects, nesting birds, and so on.

Figure 8 • 4. Harvester ants in tunnel.

Figure 8 • 5. Hills made by harvester ants.

MATERIALS

Graph paper

PROCEDURES

A. Label your sheet of graph paper as shown in Figure 8 • 6.

B. A group of biology students recorded the locations of harvester anthills in an area measuring 180 ft by 105 ft. Their table of data was similar to Figure 8 • 7. They determined how far north of the horizontal axis and how far east of the vertical axis each hill was.

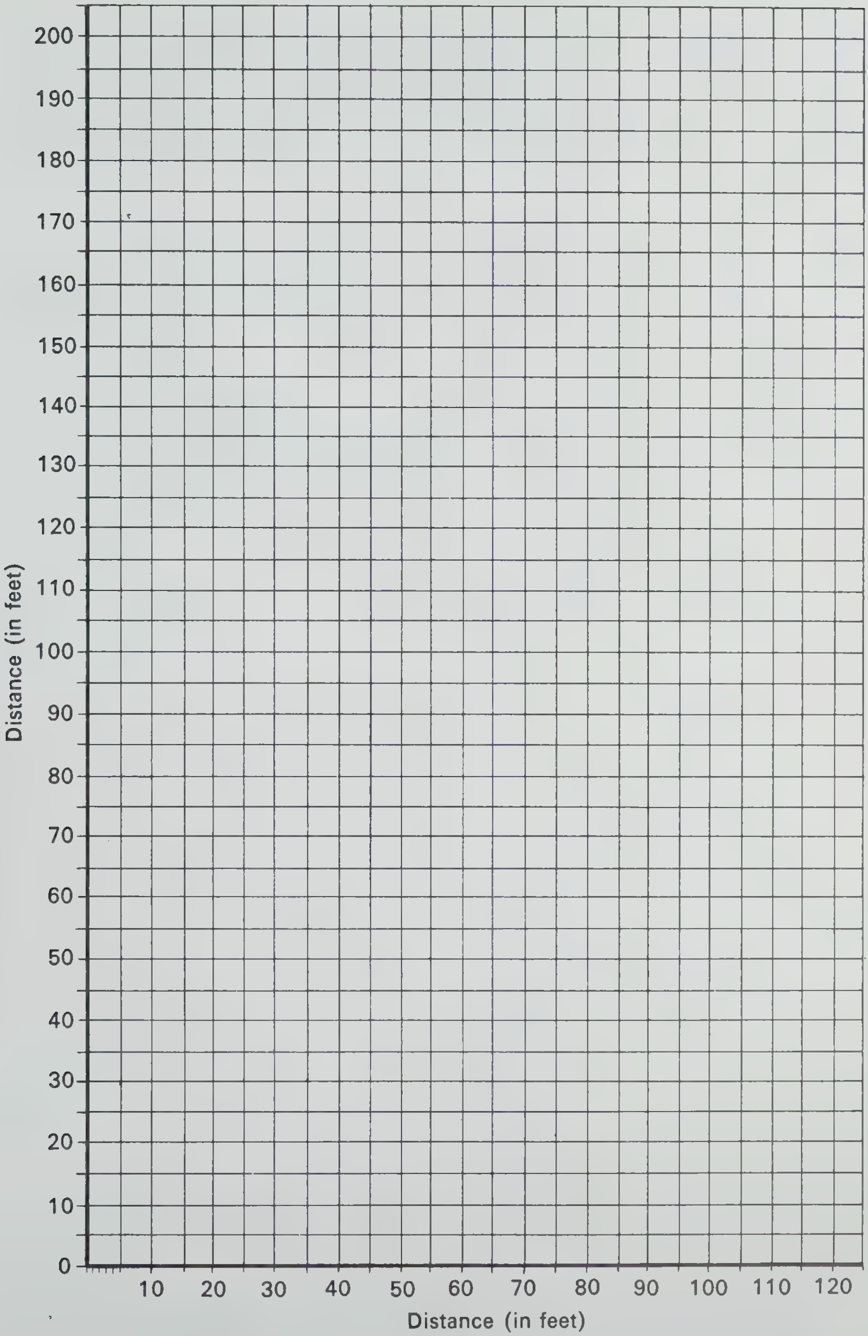

Distance (in feet)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
10 20 30 40 50 60 70 80 90 100 110 120
Distance (in feet)

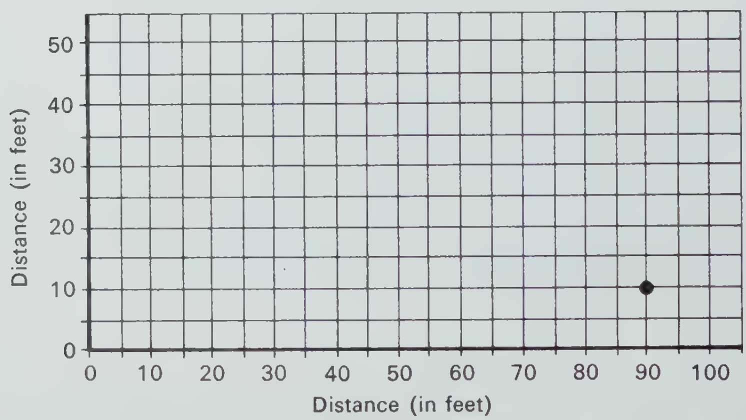
Figure 8 • 6.

Figure 8 • 7.

	Distance in Feet												
North of Zero	10	20	20	40	55	60	80	105	110	125	130	150	180
East of Zero	90	10	65	45	15	105	35	20	80	50	105	80	60

You can locate the position of an anthill on your graph by plotting the two numbers given in the table. Look up the left side of your graph paper until you come to the first number (indicating distance north). Then follow the line for that number across the paper to the right until you locate the point directly above the second number (indicating distance east). To represent the center of the anthill, draw a circle around the point you have located, as was done for Hill No. 1 in Figure 8 • 8. Plot the locations given in Figure 8 • 7 on your graph, and study the pattern they form.

Figure 8 • 8.



ANALYSIS

1. Calculate the number of square feet in the plot described in Procedure B.
2. A square 209 ft on a side has an area of about 1 acre. Find the number of square feet in an acre. Assume the entire acre has anthills distributed as in the plot you studied. Find out how many anthills there would be in the acre containing the plot.

(Divide the area of an acre by the area of the test plot. Multiply the quotient by the number of anthills in the plot.)

3. How could you estimate how many ants are in one hill? (Hint: Remember the discussion on estimating populations.)
4. Assume that an average harvester anthill contains about 10,000 ants. How many ants would there be in this acre?
5. What might account for the large open space around the point 70 ft north and 70 ft east?
6. What is the average distance between any two adjacent anthills?
7. What would happen to the ant population if the food supply was reduced for a number of years? What might happen to the distance between anthills?

Food Chains and Food Webs

Up to this point, you have been examining interactions among members of the same species. Equally important are interactions among *different* species. You have already encountered some of these kinds of relationships, for example, competition. We humans compete, directly or indirectly, with many other kinds of organisms. We try to destroy potato beetles and cotton-boll weevils because these insects compete with us for things we want—potatoes and cotton.

Food chains are made up of different species that have a feeding relationship. Plants produce their own food through the process of photosynthesis. Plants are *producers* and the animals that eat the plants are *primary consumers*. In addition, of course, there are many animals that eat the primary consumers. These are *secondary consumers*, and so on. Thus, we can think of a food chain as being composed of producers, primary consumers, and secondary consumers. Each link in the chain serves as food for the next link along the chain.

There are many kinds of animals that eat plants. These animals are called *vegetarians* or *herbivores*. Animals that eat only other animals are *carnivores*. Those that include both plants and animals in their diets are called *omnivores*. (You are an omnivore. If you ate only plant material, you would be a primary consumer. If you ate only animal material, you would be a secondary consumer.) Finally, there are species of animals and plants that live on dead organisms. They are called by several names—such as

Figure 8 • 9. What links of a food chain are shown?

scavengers and *decomposers.*

A food chain is a simple series of links, and few ideal examples exist. Usually many populations interact through several different but connected food chains. Such interactions make up a *food web.*

INVESTIGATION 8.4: Two Food Webs

In the field, it is often difficult to observe all the parts of a food web. Long periods of patient observation are necessary. Some animals eat only at night; some are so small you need a microscope to see them. Others burrow underground, and still others live in thickets. In a real food web, there are many kinds of plants and animals, and the interrelationships are complex.

In this investigation, you will construct a model of a food web, showing a few members of a large community of organisms. If you are not familiar with the eating habits of the organisms in Figures 8 • 10 and 8 • 11, you may have to do some library research. There are two lists, representing two kinds of environments. Prepare your food-web model from one of them.

Figure 8 • 10.

WATER ENVIRONMENT			
Producer	*Primary Consumer*	*Secondary Consumer*	*Scavenger*
Elodea Algae	Tadpoles Water Fleas Snails	Minnows Bluegills Frogs Bass	Crayfish

Figure 8 • 11.

LAND ENVIRONMENT			
Producer	*Primary Consumer*	*Secondary Consumer*	*Scavenger*
Trees Clover	Bees Squirrels Beetles Mice	Woodpeckers Cats Owls	Termites

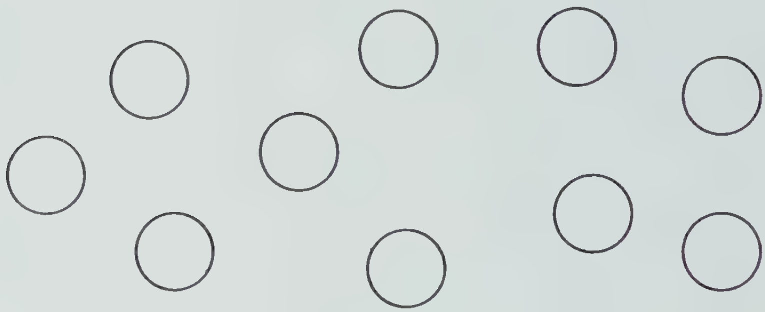
MATERIALS

Paper
50-cent piece (or other small, round object)
Pencil

PROCEDURES

A. Using a round object, draw ten circles on a sheet of paper. Arrange the circles so that they are randomly separated, as in Figure 8 • 12.

Figure 8 • 12.



B. Write the name of an organism from your list in each circle. Use each name once, and arrange the animals with similar eating habits (primary consumers, for example) so they are not clustered together.

C. Draw an arrow from each organism to every other organism that may depend upon it as a source of food. Some organisms may have several arrows pointing toward and away from themselves.

D. Assume that drawing an X through a circle means that all the members of the species it represents have been removed from the community. If you are using the water-environment list, draw an X through the circle for the snails. Draw small X's over each arrow pointing *away* from the circle. If you are using the land-environment list, follow the same procedure for the beetles.

ANALYSIS

1. List the animals that lost a source of food when the snails or the beetles were removed from the community. Next to each of the animals on this list, write the sources of food that are still available to it.
2. List the organisms that are less likely to be eaten because the snails or the beetles were removed from the community. Next to each organism on this list, write the kinds of animals that still depend upon it as a source of food.
3. For each organism that lost a source of food, make a list of the organisms that depend upon it for their food.

PROBLEM

Why might use of insecticides cause a decrease in the population of bald eagles, even though bald eagles do not eat insects?

Interactions Between Species and Their Environments

The next time you walk or ride home from school, list all the different living things you see. The more accurately you can identify what you see, the more valuable your list will be. Also, the more observant you are, the longer your list will be. Indeed, one thing you should be learning from biological investigations is to be more observant. If you are quite familiar with your home area, you will expect to see certain organisms: people, 2 black dogs, a cottonwood tree, and so on. But you may be surprised at some of the things that appear on your list.

Figure 8 • 13. Unobservant people might not see all the organisms in this photo. Look carefully at the photo, then close your book and list what you observed.

INVESTIGATION 8.5: Some Organisms and Their Habitats

Eight groups of organisms are shown in Figure 8 • 14. Seven of the groups consist of organisms likely to be found in specific kinds of *habitats*. The word "habitat" refers to the type of environment in which an organism lives. Organisms in the remaining group are not ordinarily found living together in the same habitat.

Figure 8 • 14.

1

Wheat field
Cornfield
Three crows
Pasture grass
Twenty-eight sheep
Three cows
Five broad-leaved trees
Collie dog

2

Nine sea gulls
Dry seaweed
Dead fish
Thirteen clam shells
Palm trees
Purple shore crabs

3

Maple tree
Beech tree
Oak tree
Gray squirrel
Eastern blue jay
Red-headed woodpecker
Toadstools

4

Pine tree
Wood-boring beetle
Hairy woodpecker
Currant bush
Chipmunk
Mule deer
Porcupine
Hawk

5

Oak tree
Two cats
Flies
Rat
Thirteen pigeons
Six English sparrows
Three weeds
Ants

6

American elm tree
Elephant
Peacock
Elk
Flamingo
Kangaroo
Ostrich

7

Grass
Zebra
Lion
Low tree
Giraffe
Rhinoceros
Hyena

8

Lizard
Cactus
Small bush
Roadrunner (bird)
Antelope jackrabbit
Turkey vulture

PROCEDURES

A. Imagine that eight students each reported seeing a different one of the eight groups of organisms in Figure 8 • 14. Each student made his or her observations in one of the following habitats (notice that Habitat *e* is not identified):

a. business section of a large city
b. midwestern farming area
c. African plains (savanna)
d. southwestern United States desert
e. ———
f. Rocky Mountain forest
g. forest in eastern United States
h. seashore

Try to match the numbers of the groups of organisms in Figure 8 • 14 with the letters in the preceding list. When you have only one numbered group left, assign it to Habitat *e*.

B. When your teacher indicates that you have matched the groups and habitats correctly, explain why you think the organisms in Group *e* would not ordinarily exist together in the same area of the biosphere. Where might the student who reported from Habitat *e* have been?

Ecosystems

Just as the interacting cells and tissues of an animal or plant form an organization of parts, so are organisms and their physical environment organized—into *ecosystems.* Each ecosystem is made up of two parts: a nonliving part, which can be called the physical environment, and a living part, called the biotic community. The physical environment includes climate, kind of soil, topography (mountains or plains, for example), amount of light, and so on. The biotic community, on the other hand, is made up of the animals and plants that occupy the ecosystem.

The boundaries of an ecosystem are reached where the characteristic physical environment and biotic community change. There another ecosystem begins. The biosphere is a gigantic, complicated ecosystem, but within it we can recognize smaller and less complicated ecosystems.

Notice the acorn with a hole in its side (Figure 8 • 15). The inside of this acorn is an ecosystem. An insect made the hole, and other organisms now live inside the acorn—probably some bacteria, possibly some fungi, perhaps some single-celled organisms such as you saw in the grass-water mixture, possibly a worm or an insect. The physical environment inside the acorn differs from that without. It is dark, not windy, probably moist, and acidic (because there is tannic acid in acorns).

Figure 8 • 15.

This acorn with its inhabitants is a tiny ecosystem. The biosphere is filled with all sizes of ecosystems, each of which includes complicated relationships. An ocean is a big ecosystem; a lake is a smaller one. The North American grassland from Canada into Mexico is an extensive ecosystem. The grassland that occurs on the sand hills of central Nebraska is a smaller ecosystem within the larger grassland ecosystem.

Around the world there are some very large natural ecosystems that can be easily recognized. The community you live in is perhaps surrounded by one of the *natural* ecosystems listed on page 188. Or it may be within an ecosystem that was created by people. For example, perhaps you live in a planted agricultural-cropland ecosystem. Or you may live in an urban (city) ecosys-

Figure 8 • 16. Try to match the numbered descriptions of large ecosystems on page 188 with these lettered pictures.

A

B

C

F

D

E

G

tem, which has characteristic animals, plants, and physical environment. Indeed, if you do live in or near a large city, you might want to describe this ecosystem and add it to the list.

These are some of the principal natural ecosystems:

1. Grassland: 10–30 inches of precipitation a year; cold winters; hot summers.
2. Deciduous forest (broad-leaved or hardwood trees): 20 or more inches of precipitation a year; cold, snowy winters; humid, hot summers.
3. Coniferous forest (evergreen trees): heavy winter snows; cool summers.
4. Cool desert shrub: less than 10 inches of precipitation a year; cool in winter; warm in summer.
5. Hot desert shrub: less than 10 inches of precipitation a year; mild in winter; hot in summer.
6. Tundra: cold, windy, and fairly dry; far north, far south, or high mountain areas; dwarf vegetation.
7. Temperate rain forest: wet and cool; many tall conifers; dense undergrowth.
8. Tropical rain forest: wet (seasonally) and hot; many species of organisms.
9. Piñon-juniper woodland: open forest of low trees; dry and mild most of year.
10. Chaparral: seasonally dry, mild, coastal brushland.

You can identify many of these large ecosystems by the appearance of their characteristic vegetation. The coniferous forest is made up of trees that have the shape of Christmas trees, whereas deciduous trees tend to look oval or rounded.

The photographs on pages 186 and 187 give some idea of the uniform and characteristic appearance of vegetation in large ecosystems. See if you can identify any of the pictured ecosystems. Which one is most like the area in which you live?

INVESTIGATION 8.6: An Ecosystem—The Grassland

In general, each ecosystem consists of typical kinds of plants and animals as well as a special physical environment. Both the animals and the plants in an ecosystem have adaptations (special structures or behaviors) that permit them to survive there.

Let's take the grassland as an example of a large ecosystem. These are some of its physical characteristics:

Flat or rolling countryside
10–30 inches of precipitation a year
Extremes of temperature
Long, cold winters, with occasional blizzards
Hot summers
Frequent high winds
Rich, deep soil (usually)
Much intense sunlight

PROCEDURES

A. Predict which of the following types of organisms would be found in a grassland ecosystem:

1. tree-climbing mammals
2. tree-nesting birds
3. animals with good eyesight
4. jumping animals
5. running animals
6. birds with webbed feet for wading
7. moisture-loving plants
8. seed-eating birds
9. animals with tan coloration
10. animals that hibernate (become inactive) during hard winters
11. plants with broad, thin leaves
12. birds that fly south in winter
13. brightly colored birds
14. animals that dig
15. plants, with good root systems, that live for many years

B. Predict which of the following kinds of animals would be found in a grassland ecosystem:

1. horned lark: nests on the ground; eats seeds and insects; tan coloration
2. fox squirrel: bushy tail for balance when climbing; eats nuts, fruits, and sometimes small birds; builds nest of leaves or den in hollow tree trunk; often active all winter
3. badger: long claws for digging; lives in a burrow; likes dry country; eats ground squirrels and ground birds; grayish coloration
4. falcon (hawk): tan coloration; fast flier with good eyesight; lives in open country; feeds on ground birds
5. kangaroo: lives in open country; eats grass and short plants; good jumper
6. pronghorn: excellent eyesight; fast runner; tan coloration; eats grass and short plants
7. robin: builds nest on tree branch; eats earthworms
8. grasshopper: eats grass; tan coloration; jumps; egg survives winter, but adult dies

Figure 8 • 17.

Fox squirrel

Robin

Pronghorn

Grasshopper

Falcon

Badger

Kangaroo

Horned lark

Ecological Niches of Spiders

Each kind of organism in an ecosystem exhibits distinctive physical structures, behavior, and interactions that make up what is called its *ecological niche*. An organism's ecological niche is its way of life. Another way of looking at an organism's ecological niche is to ask two broad questions: What role does the organism play in the ecosystem? How is this role carried out? Despite all the biological research that has been carried out, we still know very little about the ecological niches of most species of animals and plants.

Spiders are closely related to insects and crabs. They can be found almost everywhere, and their ecological niches are readily available for study. The black widow and the brown recluse are the only two kinds of spiders in the United States that are dangerously poisonous to humans.

Figure 8 • 18. Black-widow spider. Note the red hourglass mark.

Figure 8 • 19. Brown-recluse spider. Note the violin-shaped mark.

Although all spiders are carnivorous, the ways in which different groups obtain their food vary. Orb weavers weave circular webs that they suspend between branches of bushes and trees to snare insects. Funnel weavers make funnel-shaped webs into which they drag their prey. Common house spiders and black-widow spiders weave tangled webs. Other kinds jump upon their prey. Still others are camouflaged, hiding in flowers to grab un-

suspecting victims. These different feeding behaviors show that the various spiders have different ecological niches.

The chances are that you can find one or more kinds of spiders within a few meters if you are indoors and even closer if you are outdoors. In most areas of the country, web weavers are the most commonly seen kind. The behavior of spiders can be observed either in their natural environment or in the laboratory. You might wish to observe it in both places, depending upon where you live.

INVESTIGATION 8.7: Observing Spiders

Part I. Spiders in Nature

MATERIALS

- Notebook
- Flashlight
- Collecting jars with lids

PROCEDURES

A. The first step in observing web-weaving spiders in their natural environment is to locate a web. Webs are usually found where insects are present—which is just about anywhere. Good places to look are around windows; under eaves; in basements, garages, or attics. Look around barns, sheds, and rock and wood piles; in gardens, brushy areas, and grassy fields; near ponds or streams.

B. Once you locate a web, record its location and structure. Try to find its occupant. Spiders may be seen in the center of their webs (orb weavers), in tunnels leading away to dark areas (funnel weavers), or around the webs' edges. Sometimes a spider may sit quietly on a single strand of "silk" well removed from the main web. Since many spiders are nocturnal, you may locate them most easily at night, with the aid of a flashlight. Look for their eyes; they will shine when the light hits them. Spiders often spin webs near outdoor lights. Here they wait for insects attracted by the light to fly or crawl into their webs.

Figure 8 • 20.
What type of spider spun this web?

C. While making as few movements as possible, observe a web for five minutes or more. If an insect becomes trapped in the web, you may see a spider dash out to the insect, possibly performing in one of a number of ways: It may (*a*) bite its prey and quickly return to its hiding place, (*b*) start feeding on the insect or drag it away to eat it in solitude, (*c*) begin the process of wrapping the insect in "silk" in preparation for a future meal, (*d*) struggle unsuccessfully with the insect, which finally escapes. Record any observations.

D. Some spiders will repair broken parts of their webs; others will not. Try breaking a small part of a web and see if it is later repaired. This may require observations over several days. Record your observations.

E. See if you can tease a spider into coming out of hiding by tossing a small, flying insect into its web.

F. If you have a good camera with a flash attachment, try to photograph different spiders and spiderwebs. This is usually difficult and provides a real challenge to a photographer.

When observing web weavers out of doors, be on the lookout for other kinds of spiders. You may see a jumping spider jump on its prey or a wolf spider run after its prey. You may want to collect one or more spiders for future observation in the laboratory, so always carry a few collecting bottles.

G. Prepare a report on your observations of the behavior of spiders in their natural habitat.

Part II. Spiders in the Laboratory

It may be difficult for you to spend enough time outdoors to observe spiders in their natural habitat. Regardless of where you live, spiders can be collected rather easily and transferred to jars or cages for study in the laboratory. (Refer to Appendix B.)

MATERIALS

Cage with established spider
Notebook
Live insects

PROCEDURES

A. Place the caged spider where it will not be disturbed and where you can easily observe it.
B. Observe the spider over a two- or three-day period. Record your observations from time to time.
C. Place a live insect in the cage with the spider. Record your observations.

ANALYSIS

1. Why is it important that you not disturb your spider and that you observe it for a few days before feeding it?
2. How does your spider react when an insect is placed in the cage?
3. What special structures does your spider have for catching insects?
4. After it is through feeding, what does your spider do with the insect? Do other kinds of spiders behave the same way?

ON YOUR OWN: Spider Study

Plan and carry out experiments to answer the following questions about your spider: Will it eat dead insects? How often will it eat? Does it repair a damaged web? If so, how does it go about the repair? Will it eat meat other than insect tissue? What effect does temperature have on it? What effect does light have on it?

Dispersal of Plants

By now you should realize that each ecosystem has a specific group of plants and animals. Ecosystems, large and small, are present throughout the biosphere, even on isolated oceanic islands and in isolated ponds. Have you ever wondered how living things, especially plants, could have become so widely distributed in all the ecosystems?

You may remember that the movement of organisms into and out of a region is called dispersal. You will soon discover that both plants and animals have many methods of dispersal—through interactions either with the physical environment or with other organisms.

Some plants, such as ferns, mosses, and mushrooms, have no flowers. They disperse by means of *spores*. Spores are something like seeds, but they are very much smaller. A single spore can be seen only with the aid of a microscope. The spores are in a plant's *spore case*. When spores are ripe (ready to grow into new plants), the case breaks open, releasing them.

Figure 8 • 21.
Moss spore case.

If you can find some ferns, beat a few of the older ones on your hand. You may see spores flying like dust from the cases under the leaves. Something else you can do is to place some mushroom caps (topside up) on light and dark paper overnight. The next morning you may see a "print" of where the spores were shed.

Because spores are very light, they are easily carried long distances by the wind. When a spore comes to rest and meets favorable conditions, it may become a new plant.

Most of the plants familiar to you are flowering plants. They disperse by means of seeds, which are found in the flowers. Seed plants have many methods of dispersal.

Some seeds are carried by the wind. Some are carried by water. Have you or your pet dog or cat ever come home covered with sticky seeds? Seeds may also be carried by birds. Birds ordinarily *eat* seeds; but if the seeds are carried to a nest or to a hiding place, some may be dropped along the way. In these and other ways, seeds are carried to new areas, where new plants will grow if conditions are right.

Dispersal of Animals

When our ancestors began building towns and cities in North America, they destroyed large areas of natural ecosystems. In so doing, they eliminated many of the animals and plants that were living in these areas. This created many empty places in the natural community of organisms; the empty places were rapidly filled by rats, house mice, pigeons, cockroaches, dandelions, and other species that could live close to human habitation. Many of these species came from the Old World, where they had long been unwanted guests in human communities. The English sparrow and starling were brought from Europe into our country. Now they are considered pests by many people. But some immigrant species, such as the ring-necked pheasant from China, are still welcome.

In the late 1800's, English sparrows were brought to New York and San Francisco from England. The sparrows built nests

Figure 8 • 22.
English sparrows.

in the eaves of houses and barns. Every pair of sparrows raised about 3 young each time they nested, and on the average they nested more than twice a year. Thus 6 new birds (per pair) were added to the population each year. Most birds are ready to nest when they are a year old. At this rate, if there were 2 sparrows to begin with, two years later there would be nearly 50 birds, and after three years there would be about 150. When a young bird is a year old, it competes directly with its parents. If there are not enough nesting places or food in the area, the more experienced parents will force the young to leave.

Although a pair of English sparrows will allow another pair to nest as close as 2.5 or 3 m away, few houses or barns can support more than five or six pairs of sparrows. Since five pairs can produce at least 30 young birds in a year, many of those 30 must move out and find their own houses and barns.

Less than ten years after arriving in San Francisco, English sparrows had expanded their range to include most towns in the central part of California. By 1907 they had reached Los Angeles, and by 1913, San Diego. In the meantime, those brought to New York had expanded their range west to the Rocky Mountains and south to Arizona and Nevada. By 1920, only 60 years after their first arrival in the United States, English sparrows inhabited nearly every part of every state and had spread throughout southern

Figure 8 • 23.
Barn owls.
Above left: Young.
As the young owls mature, they begin to compete with their parents for food and space.
Above: Adult.

Canada and into northern Mexico. The movement of the extra birds is another example of *dispersal*. It is the result of overpopulation in one area. The extra birds have to move out or die.

Many larger mammals—wildcats and coyotes, for example—also experience the pressure of population; each species expands its range to all areas that provide it with enough food and a place to live. Large mammals cannot cross wide bodies of water, so they are generally limited to connected land areas.

In the past, human beings have escaped the pressures of overpopulation by moving to new areas. Now, few uninhabited land areas remain except those in which natural conditions make life very difficult, such as Antarctica or the great deserts of the world.

FOR FURTHER ACTIVITY

Look for sow bugs or pill bugs under rocks, logs, or boards lying on moist ground. A sow bug or pill bug carries its young in a pouch on the underside of the body. In the same kind of surroundings, you can find wolf spiders carrying young on their backs. In ponds you may find large bugs that carry eggs on their backs. Tent caterpillars can be found among tree twigs and leaves in the spring. If you watch closely, you can see butterflies laying their eggs on leafing plants. A few snails or frogs or salamanders may lay thousands of eggs.

Find as many eggs of one kind as you can and count them. Even if only half the organisms hatching from these eggs lived and bred, how many might there be in three years? Does this suggest enough overpopulation to cause strong pressure for dispersal?

Figure 8 • 24. Wolf spider with young on its back.

Change in Ecosystems

A tourist was once staying at a hotel near Rocky Mountain National Park, a beautiful wilderness area with high peaks, mountain lakes and meadows, glaciers, and an enormous variety of animals and plants. He seemed to be spending all his vacation in a rocking chair on the porch. Finally, someone asked him when he was going to visit the national park. "Oh," he replied, "I was here once before and saw the park then."

This man certainly didn't know much about the changing world he lived in. In any ecosystem—and a national park is made up of many different ecosystems—no two moments are alike. All kinds of changes are taking place: from minute to minute, from

daytime to nighttime, from winter to summer, from year to year, even from century to century.

Some changes you are likely to have already noticed are those associated with time of day. Some organisms are active at night, and other kinds are active during daylight. Have you ever noticed that most birds are active only during the day? What happens to them at night? Many small mammals (such as certain mice) are active mainly at night. There are even some kinds of plants that are more active at night than in the daytime.

All organisms, including human beings, have *biological clocks* —which influence natural reactions to time. Ordinarily, you are probably not aware of your biological clock. But if you stay up much later than usual or skip a meal, you may feel some discomfort. If you fly across two or more time zones, it may take several days for your biological clock to adjust to the new times of sleeping and eating. (What effect do you think supersonic-jet travel across many time zones will have on people's behavior?) Worst of all, if your clock is set so that you are a "night person," you may spend a lifetime trying unsuccessfully to adjust to a world scheduled by "day people"!

One way you can observe differences in activity related to time of day is to count the number of automobiles that pass your home on a Saturday. Count the number going by in both directions during a five-minute period every two hours from early morning through midevening. On Monday your results can be compared with those of other students and then charted. How would your figures differ if all human beings were most active at night and tended to sleep all day? How would the number counted on a Saturday night compare with the number that could be counted on a Monday night?

Ecosystems also change on a seasonal basis. That is, there may be different organisms present and active during different seasons of the year. Hardly any insects, for example, are seen in the wintertime in cold climates. Thus, those insect-eating birds that spend the winter there (rather than flying south to where insects are still active) live on insect eggs or on hibernating adult insects and spiders that they find under bark, leaves, and so on.

Succession

Other changes in ecosystems may take place over very long periods of time. For example, there may be a gradual replacement of one group of organisms by another. Such changes are called *succession.* Though some kinds of ecosystems may change fairly rapidly, others may not change for centuries.

A good example of succession is the sequence of changes in a pond over long periods of time. At first, a pond may just be open water, fine for boating and swimming. Later, some aquatic plants may establish themselves in the pond. Land plants may begin to invade the shoreline. Eventually the pond may disappear completely, being replaced by a meadow and perhaps later by a woodland.

The first organisms to appear in succession are called pioneers. Those that survive are hardy, just as human pioneers on the American frontier had to be. Land-plant pioneers invading ponds have to be able to survive under wet conditions. In contrast, other kinds of pioneers succeed in dry, rocky areas. The first pioneers on rock often are *lichens.* A lichen is made up of two different kinds of organisms, a fungus and an alga, which live together. Lichens actually change the physical environment on rocks. By holding moisture and by breaking down fragments of rock, they form a trace of soil. This soil makes a suitable habitat for the growth of higher plants, such as mosses, grasses, wild flowers, and perhaps eventually trees.

Many of the most successful pioneer species are weeds. People generally think of weeds only as pests. But weeds play an important role in the development of ecosystems. In time they will be replaced by more stable, long-lasting species of organisms if succession is allowed to go on undisturbed.

Figure 8 • 25. Lichens growing on a rock.

Figure 8 • 26. Evidence of succession in a pond. This pond may eventually disappear, leaving meadow, as seen in the background.

Figure 8 • 27. These photos show succession after a forest fire that occurred in 1911. The pine forest is being reestablished. Note the growth of individual trees and the change in and around the tree stump shown in the right foreground. Predict what a picture taken in 1992 might look like.

1911

1938

1958

1972

INVESTIGATION 8.8: Succession on a Microscope Slide

Succession usually takes place over long periods of time. Its slow changes often go unnoticed. However, some kinds of succession do take place quickly. You should see an example of rapid succession in this investigation.

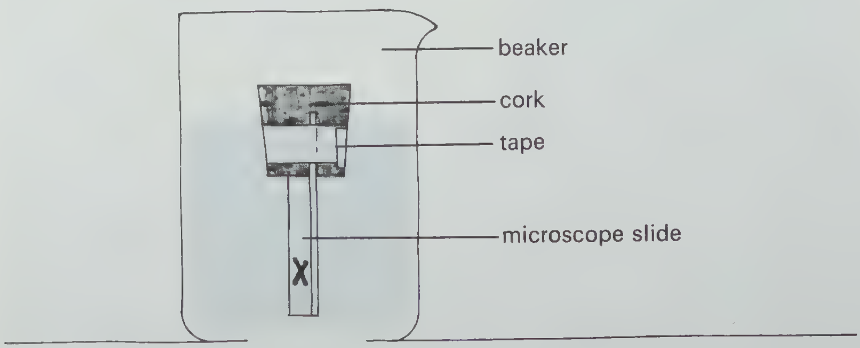
MATERIALS

- Large cork
- Microscope slide
- Beaker or jar, 250-ml
- Grass-water mixture, pond sample, aquarium water, or culture of mixed microorganisms, 200 ml
- Knife or single-edged razor blade
- Glass plate or aluminum foil

PROCEDURES

A. Starting midway across its narrower end, cut a slit about halfway through the cork. Rub a microscope slide on your hair. Insert the slide in the cork as shown in Figure 8 • 28. Using a grease pencil, write an X on the side of the slide that you rubbed on your hair.

Figure 8 • 28.



B. Pour the water from your pond sample into the beaker and float the cork and slide in it. Cover loosely and set aside for 24 hours.

C. Next day, dry the side of the slide without the X. Examine the wet side, using a microscope. Try to identify any organisms you see, with the aid of Appendix H. Make a list of these pioneers in your data book. Replace the slide in the beaker and set aside again.

D. Two days later, repeat Procedures B and C.

ANALYSIS

1. How many *kinds* of organisms did you see after 24 hours? After 48 hours?
2. After 24 hours, were the organisms mostly of one kind? If so, what kind? After 48 hours, had this changed? How?
3. Try to explain what happened in the water sample in the time between your two observations.

Climax Ecosystems

Succession generally seems to end with an ecosystem that maintains itself for many years. It is called a *climax* ecosystem. It will usually maintain itself as long as the climate remains the same. A climax ecosystem tends to include fewer kinds of organisms than were present at earlier stages of succession.

Indians in the early North American wilderness (present-day Canada and the United States) understood the effects of succession. They knew that there is a greater variety of organisms in successional stages than in climax ecosystems. And usually the kinds of animals and plants upon which Indians depended for food and other things were found mainly in successional areas. Thus, many Indian tribes would burn climax forests so that stages of succession involving brushland and meadows could begin again.

Every time an ecosystem is disturbed, succession begins again. You can see many examples of succession following human activities in your own area: in burned forests and burned houses; on abandoned sidewalks and highways; in pastures and vacant lots; in the ocean, on shipwrecks or pier pilings. Look around for examples of such succession, and bring a description to class for discussion. If possible, draw or photograph some plant pioneers and bring the pictures. You may want to identify some of the common pioneers, but it is just as important to find out if the pioneers you saw are the same as those seen by other students in the same kind of area.

Once started, succession continues until it is interrupted or until the climax ecosystem typical of the region develops. For example, if a deciduous woodland in western Pennsylvania is logged, the woodland may eventually come back. The deciduous forest is the typical climax ecosystem for western Pennsylvania. Before the woodland returns, however, there may be a pioneer weed ecosystem for a while, then a grass ecosystem, and then a brush ecosystem. Thus, there may be a whole series of successional ecosystems, sometimes over a period of many, many years, before the climax ecosystem—the deciduous forest—returns.

Ecologists are continually learning more about long-range successional changes in ecosystems. And some of the findings are surprising. For many years, it was thought that the giant sequoias (redwoods) of the California Sierra Nevada represented a climax ecosystem. Many of these forests have been carefully protected from as early as 1864. Only recently was it discovered that the Sierra Nevada sequoias are actually a stage in succession—the kinds of evergreens that have been growing up in their shade during many years of protection will eventually replace them. What a shock for ecologists! Now they will have to destroy the undergrowth to preserve the giant sequoias.

ON YOUR OWN: The Environment Revisited

One of your first activities in Section One was to examine the environment around where you live or go to school. Recall that you were asked to list and identify as many kinds of organisms as you could see and to include any evidence you could find of the recent presence of an organism. Finally, you were asked to look for interactions occurring among different organisms.

Now, after completing about two-thirds of the course, you should know much more about the environment—the many kinds of organisms that inhabit it and how they interact with each other and with their environment. Therefore, you should be able to revisit the same areas visited in Section One, list and name many more kinds of organisms found there, and find evidence that other organisms have been there recently. Interactions should be more evident to you now than before.

In this investigation you are asked to repeat that first activity. Look for such interactions and describe them. Select a particular organism and try to describe its ecological niche. Record any interactions that you observe. Compare your observations with those you made in Section One.

If you carry out this investigation carefully, you just might see an interaction no one else has seen. This time no hints of what you should find are given. You are truly on your own.

Extending Your Knowledge

Sheep ranchers in a mountainous area of the country became alarmed because they thought mountain lions were killing their sheep. The ranchers set out to destroy the lion population with poisons, guns, and traps. Within two years their sheep were no longer killed by lions. Nor were the mule deer, which lived in the brushy sites and browsed (nibbled) on the bushes. The campaign to get rid of the lions appeared very successful.

A well-known ecologist visiting the area noticed that most of the natural brushy vegetation was dying. He observed that something had apparently eaten the leaves and twigs of almost every shrub in the area, thus badly damaging them. He blamed the damage of the natural vegetation on the widespread killing of mountain lions. Do you think the ecologist was correct? If so, what do you think the killing of mountain lions had to do with the damage of the bushes?

Life at the Edge of the Sea: A Marine Ecosystem

Figure 8 • 29. The edge of the sea is one of the richest places for life in the entire biosphere. The seawater contains the minerals needed for life, and more are constantly washed in from the land. Through tides, waves, and currents, the movements of the water are constantly bringing new materials to all the animals and plants that live in the shallow waters at the edge of the sea. On most coasts, the tide reaches a high (*above*) twice a day, and in between it may be several meters lower.

Green plants are necessary for all life—in the sea just as much as on the land. The photo at the right shows a rich growth of seaweeds on the rocks exposed at low tide. There are many other sorts of green plants in the water, including microscopic algae that are somewhat like the kinds you observed in the grass-water mixture.

Many animals can be seen when one pokes among the seaweed or turns over the rocks in a tide pool—a depression in the rocks that retains water when the tide is low. A starfish (*below, left*) slowly moves—by tube feet on its underside—across the surface of a rock in a tide pool. Notice also the green-, brown-, and reddish-colored algae. Snails (*below, right*) are commonly found on rocks that are exposed at low tide. At high tide, when the snails are covered with water, they move over the rocks, feeding on plants and organic matter.

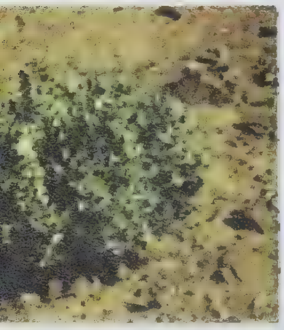
Many kinds of birds and mammals live at the edge of the sea. Some feed on smaller animals, but ultimately all depend upon the plants. Above is a dark-colored cormorant and a lighter-colored sea gull. Cormorants feed largely on fish, which they grasp with their strong beaks as they swim under the water. Gulls are primarily scavengers. They eat the remains of dead organisms and, if people are nearby, the garbage dumped into the sea. Below is a group of sea lions resting on the rocks. They live on fish that they catch in the sea.

Life in Death Valley: A Desert Ecosystem

Figure 8 • 30.

Right: You are standing on a mountain about a mile high, looking down into one of the hottest and driest places on Earth—Death Valley. The average rainfall is less than 2 inches a year, and in some years there is no rain. The highest temperature ever recorded in the shade is 134°F, but the surface may reach 190°. The white material on the floor of the valley is salt. This hardly sounds like a place where animals and plants can live. Could it be that life is possible here for green plants? And if there are sufficient plants, will animals also be found? Death Valley is one of the most difficult places in the world for plants and animals to live in.

Below, left: The lowest point in North America. It is 86 m (282 feet) below sea level. There are salt deposits in the foreground, a pool of very salty water, and then the cliffs. The small white sign near the top of the photograph marks sea level. Even here there is life. *Below, right:* A portion of the pond. Green plants are growing along the edge of the salty water. There are other green plants in the water—and a rusty beer can that someone has thoughtlessly discarded. Can you find it in the lower right-hand corner? There are insects, spiders, a few birds, and a few lizards.



In those parts of the floor of Death Valley where the soil is not too salty and there is some underground water, there are plants. *Above, left:* A clump of mesquite bushes. These are taller than a man. Their roots may go down 20 m (60 feet) to water. The mesquite is one of the most important plants here. Its beanlike seeds (*above, right*) provide food for many of the animals here, and, in earlier times, provided it for the Indians. The plants also provide shade—protection from the intense light and heat. A few other types of plants can live here, for example, the salt bush (*left*). A few insects, birds, and reptiles can be seen during the hot hours of the day. Most animals spend this period in burrows, however, and come out at night, when it is cooler. Notice all the tracks at the entrance to the burrow in the photograph below.

Lizard

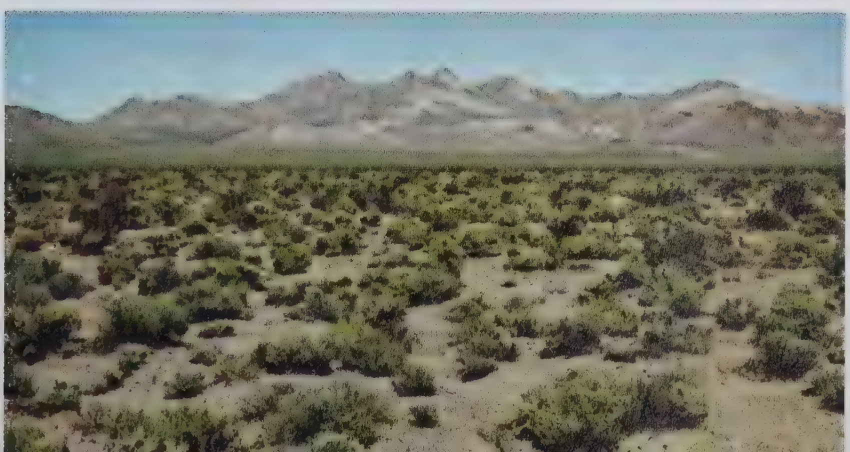
Burrow

Coyote

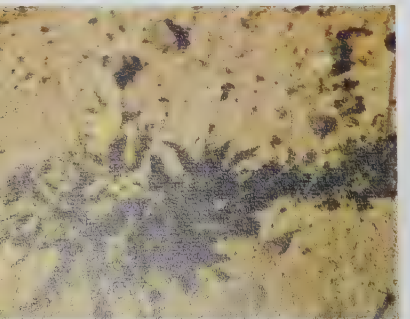
The environment is so harsh in some areas that there are few plants or none.

This dark, volcanic soil can support a few widely spaced plants.

At higher elevations there is less heat and a little more rain. Plant life is more abundant.



Here there is enough plant life to support a herd of wild burros (*below*), descendants from those used by miners long ago.



The four main things that green plants need are light, air, water, and a suitable soil. Deserts have a great amount of light (cloudy days are rare), plenty of air, and often a soil full of the needed minerals. Water is always a problem, and the hotter the region, the more water is required by plants and animals. Sometimes there is a spring, and an oasis is the result (*above*). In many areas of deserts there are few plants during most of the year. When the rains come, the "dead" floor of a desert may blossom with an abundance of flowers.

Close-up photographs of two desert blooms.

SECTION NINE

Mankind in Nature

For a number of weeks, you have been investigating interactions among organisms and between organisms and their environment. This has been a general overview of ecology. Now you will focus your attention on one particular species of the biosphere—human beings.

If you were to take a trip around the world on a jet liner, your view of the earth's surface would reveal many signs of human activities: the great checkerboard of farmlands; sprawling, smoke-covered cities; endless highways, railways, and canals; huge dams and artificial lakes; the scars of mining.

What do all these observations indicate? Just that it is hard to find a place on the earth today where people have not interacted with the biosphere. Thus, as we look at organisms in the biosphere, it makes sense to focus first on human beings. This is partly because we are humans, but more importantly because no other living things have had such a great effect on the biosphere, especially in such a short period of time.

A few thousand years ago, the impact of humans on the biosphere was small. Their numbers were few. They hunted, fished, and collected wild plants for food. They fashioned spears and bows and arrows. And they were the hunted as well as the hunters.

Through the centuries people learned to make and use more complicated tools. They learned to plant seeds to ensure a crop of food every year. They domesticated animals, providing themselves with a source of meat, milk, hides, and companionship. Their power as hunters increased as their weapons improved. Because these various activities were helpful to them in living within the biosphere, more human beings survived. Slowly the population grew.

During the Middle Ages in Europe and Asia, there were new advances in science and technology. People were beginning to use their increasing knowledge to *control* the biosphere, not just to study it and live within it. Along with the urge to control nature was an urge to explore the world—and technology made both control and exploration easier.

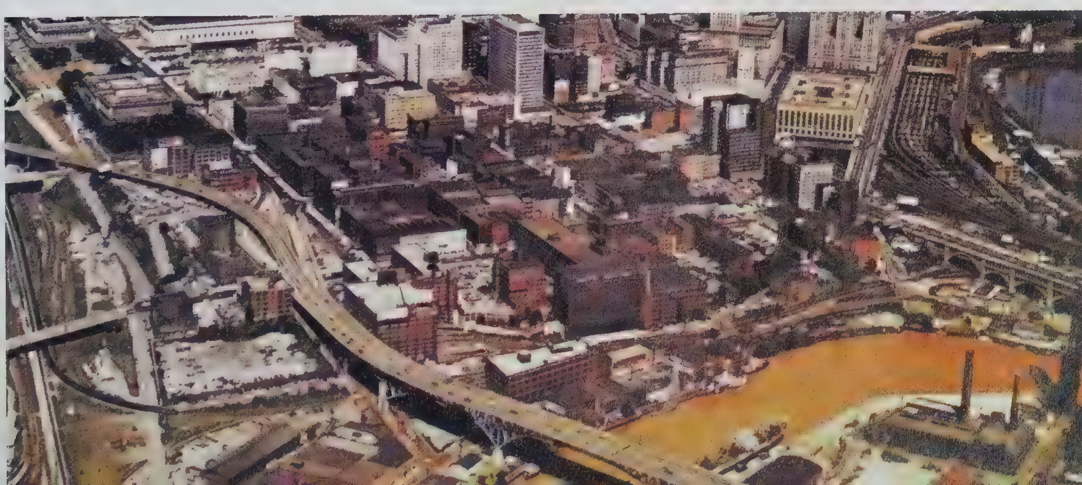
By 1776 Captain Cook was on his third voyage around the world, James Watt had perfected the steam engine, spinning machines had been invented—the Industrial Revolution was under way. The world and its resources were coming under human control.

When French explorers penetrated the New World as far as the present state of Ohio late in the 1600's, it was a forested wilderness populated by about 15,000 Indians. But look at Ohio today, only 300 years later. Where a few thousand Indians once hunted, fished, and gathered food, there now live about 11,000,000 people, three-quarters of them in cities.

Advances in industry, agriculture, medicine, and education have together made possible this large population in a heavily industrialized state. Most people who hunt and fish in Ohio now do so for recreation. They "gather" their food at supermarkets. A few farmers, with special machinery and scientific know-how, grow enough food to support the population. Other people are involved in activities that the Indians never dreamed of: making electric lights, repairing TV sets, pumping gas into cars, selling insurance, or going to school.

When the explorer La Salle came to Ohio in 1670, he saw few signs of people's effects on the biosphere. Today it would be easy to find evidence of human activities almost anywhere within the state of Ohio—even above it, in the air.

Figure 9 • 1. Cleveland, Ohio—300 years after La Salle.



Our Imprint on the Earth

Figure 9 • 2. Our activities are having a growing impact on the biosphere. Evidence of them takes many different forms.

Top: Cultivating the earth for food. *Bottom:* Building cities for shelter and commerce.

Building airports
for transportation.

Strip-mining
for minerals.

Left below:
Damming rivers
for irrigation,
power, and
flood control.
Right below:
Drilling for oil
beneath the ocean.

An Explorer's View

In Europe and Asia, the impact of people on the biosphere has been apparent for a long while. On the other hand, in our part of the biosphere their impact has only become significant within the past few centuries. All of North America was still wilderness when Columbus visited the New World in the 1490's; and even 300 years later (in the 1790's), much of the western part still remained unexplored—remember that the Lewis and Clark Expedition did not cross from the Atlantic to the Pacific until 1805.

Many of the early explorers wrote diaries about the wilderness country through which they traveled. These accounts are obviously very different from a diary that might be written about the same country today. In 1679, for example, Father Hennepin, who was traveling through the Great Lakes region with La Salle, wrote this description of the area around Detroit, Michigan, which today is a highly industrialized metropolitan center:

> The country on both sides of this beautiful strait is adorned with fine open plains, and you can see numbers of stags, does, deer, bears, by no means fierce and very good to eat, water fowl, and all kinds of game, swans in abundance. . . . The rest of the strait is covered with forests, fruit trees like walnuts, chestnuts, plum, and apple trees, wild vines loaded with grapes, of which we made some little wine. There is timber fit for building. It is the place in which deer most delight.

Today, people are making a much greater impact on the biosphere than they made in the past, especially in the distant past. This is in part because of the different things people do now but also because there are many, many more people, harnessing much more energy, using more powerful and varied tools, and demanding greater quantities and varieties of natural resources. This increased demand has, among other things, resulted in various forms of pollution.

ON YOUR OWN: A Look Back

Wherever you live, there have been explorers and colonists in the past who wrote descriptions of the region as they first discovered it. Find out from a history book or a social-studies teacher about the early visitors to your region. Then look up anything these visitors may have written, using the school library or your public library. Some communities have historical societies with valuable collections of books. Your historical society may have published a magazine including articles about your region. Try to locate one of these early accounts and compare it with what your area is like today. Copy some of the original descriptions of your area and share these with the rest of the class. It would be valuable, if you find old pictures of your region, to compare the way it used to look with the way it looks today. You should find interesting comments about the scenery, the geology, the climate, the vegetation, the animal life (especially game animals), and the native inhabitants. Which of these have changed the most, and how?

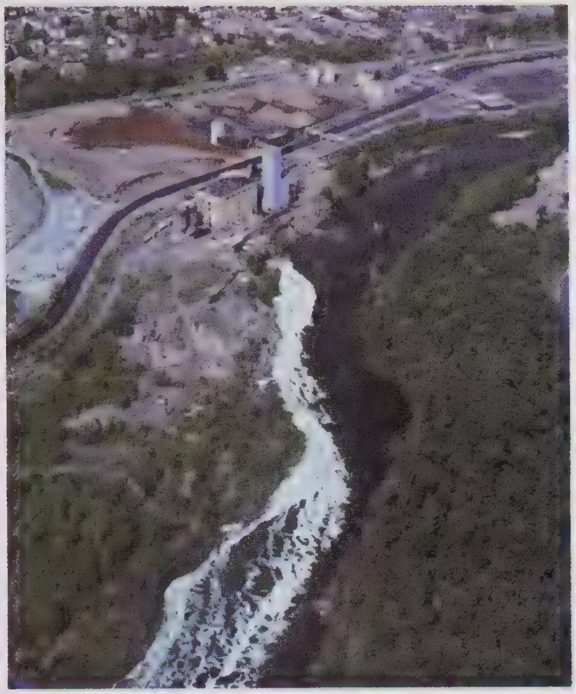
Pollution

At one time it was believed that the oceans were so vast that pollution of them would never become a problem. But human use of the oceans has increased greatly. For example, much oil is now transported from one country to another in ships. Oil leaking or spilled from tankers has caused some serious pollution. Many people are becoming concerned about the amount of such pollution and its effects on marine life. Much of the world's population is dependent upon marine life for food, and this dependency is likely to increase as the demand for food increases. Also, much of the biosphere's oxygen is produced by plants in the oceans.

The coastline near Santa Barbara, California, has long been considered an example of natural beauty. Tide pools that contain a variety of marine organisms are scattered along the coast. The beaches have an unusual assortment of plants and animals. But human carelessness has influenced this area, too.

In 1969 oil began seeping from cracks in the ocean floor near an offshore oil well. A giant oil slick spread over hundreds of square kilometers, covering Santa Barbara's coastline. Birds and

Figure 9 • 3. West Beach, Santa Barbara, California. Over 36,000,000 liters of crude oil reached southern California beaches during early spring, 1969.



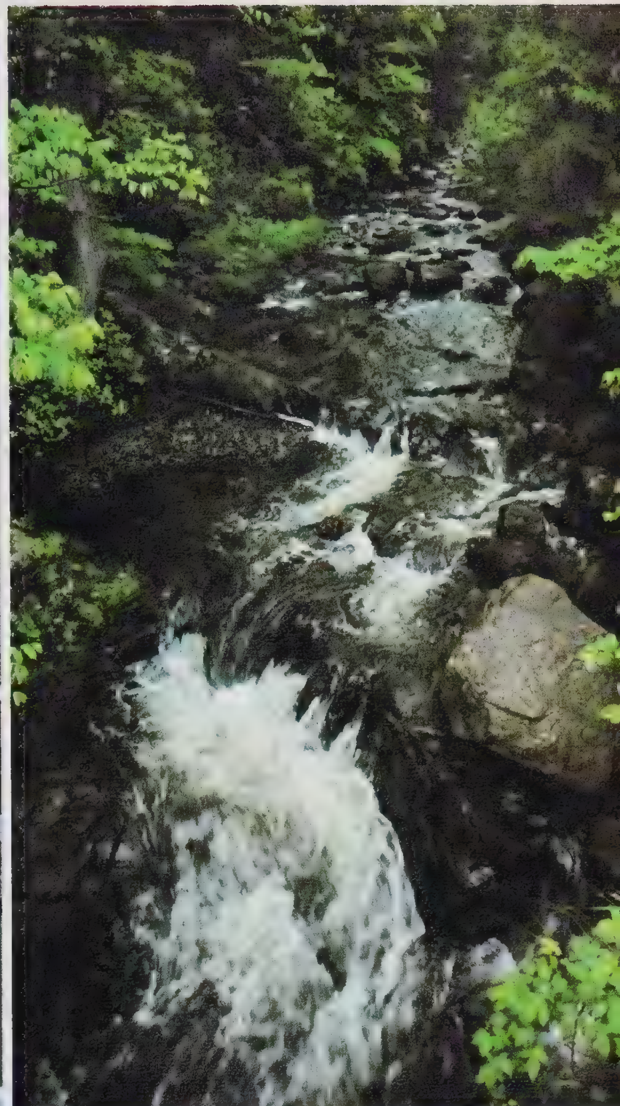


Figure 9 • 4. How long does it take to ruin a river? The Hudson begins as a pure mountain stream high in the Adirondack Mountains of New York. Within 16 km (10 miles) of its source, strip-mining begins to pollute the river. Within less than 160 km (100 miles) of its source, it receives the raw, white wastes of paper mills. By the time the Hudson reaches the northern suburbs of New York City, industrial and municipal wastes have changed its color to that of an asphalt parking lot. As it flows past the Statue of Liberty, 510 km (315 miles) from its mountain beginning, it is little more than an open sewer.

fish were destroyed, and once-beautiful beaches were covered with a gooey mess of crude oil. Of course, oil pollution is not limited to the coast of California. It has occurred in oceans and seas throughout the world.

Oil, however, is not the only cause of water pollution. People have dumped trash, raw sewage, and industrial wastes directly into the oceans, lakes, rivers, and streams for years. If such spoiling of the world's water resources continues, people will have to accept the consequences. Try to imagine what the biosphere would be like without any usable water!

Fresh water that was once considered fit for humans is now becoming unfit for any form of life. Few cities have water that can be used without first being treated in purification plants.

A great many cities are now faced with another kind of pollution—pollution of their air. Smoke, fumes, and dust are the common offenders. Those of you living in large cities are probably well acquainted with *smog*. This term originally referred to a mixture of fog and smoke given off by factories and automobile engines. Today "smog" is used to refer to many kinds of visible air pollution. Smog sometimes becomes so dense that a person's eyes "burn" continuously. When it is thick enough—and it often rises above the danger levels established by public health officials—it can cause illness.

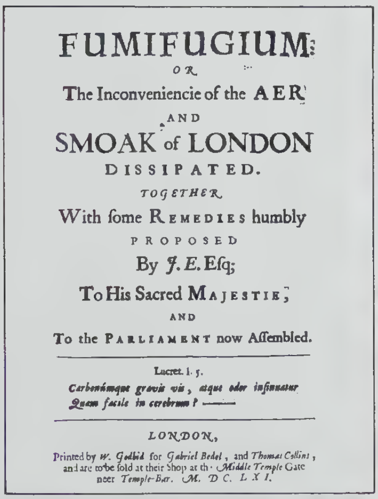
Areas having damp, poorly circulated air tend to develop worse smog problems than areas with dry, well-circulated air. Residents of Los Angeles, Chicago, and New York City, for example, have lived with smog for a long time. Denver, Colorado, is 1½ kilometers (1 mile) above sea level. It used to be considered an ideal place for people suffering from respiratory diseases. Today Denver also faces a serious smog problem. All large cities produce air pollution, which tends to rise into the atmosphere above; then it may spread for hundreds of kilometers. Some scientists think such pollution may be causing changes in the temperature of the earth's atmosphere—changes that could have long-range effects on life.

Today many automobiles still operate best with ethyl gasoline, which contains a lead compound. Thus, tiny particles of poisonous

lead are being spewed into the atmosphere daily, adding to the general pollution of the earth's atmosphere. Even the long, white trails that you see behind jet aircraft are evidence of pollution in our atmosphere. These trails are made up of water droplets that form around unburned particles of jet fuel.

What all this means in terms of seriously harming the biosphere is not yet completely known. However, many scientists have already predicted that unless something is done to correct

Figure 9 • 5. Smog has long been a problem in London, England. Below, left, is the title page of a book about it printed in 1661; bottom, left, is a photo of London taken November 18, 1953, at noon. During a similar "killer smog," an estimated 4000 persons died. London has since reduced its smog problem greatly, as the aerial view shows.


FUMIFUGIUM:
OR
The Inconveniencie of the AER
AND
SMOAK of LONDON
DISSIPATED.
TOGETHER
With ſome REMEDIES humbly
PROPOSED
By J. E. Eſq;
To His Sacred MAJESTIE,
AND
To the PARLIAMENT now Aſſembled.

Lucret. l. 5.
Carbonúmque gravis vis, atque odor insinuatur
Quam facile in cerebrum? —

LONDON,
Printed by W. Godbid for Gabriel Bedel, and Thomas Collins, and are to be ſold at their Shop at the Middle Temple Gate neer Temple-Bar. M. DC. LXI.

these hazards, our one supposedly inexhaustible resource—air—may become so contaminated it can no longer support life as we know it.

Something *can* be done if people are alerted to the dangers and are willing to do something about them. Already new types of jet engines that will leave less unburned fuel have been designed, and some are already in use. Also, recent models of automobiles are all equipped with devices that limit the amount of pollution produced. Perhaps someday cars driven by steam or electricity will replace those using gasoline. Efforts have been made to reduce the smoke given off by factories. This is difficult, partly because the methods used are expensive and partly because the development of more effective methods costs additional money. Despite the obstacles, if our environment is to be livable, we *must* decide to spend the money, time, and effort required. Pollution will not go away by itself; only people can stop pollution.

How often have you gone to the country for a hike, a picnic, or a field trip only to find that people before you had picked the flowers, dug up plants, carried away rocks, and littered the area with plastic bags, aluminum cans, and so forth? Trying to enjoy such an area is difficult, and trying to learn much about its natural plant and animal life is almost impossible. (You should keep this in mind when collecting specimens for this or another biology course. You can photograph or sketch specimens instead of taking them away with you. If you have to collect, you can always take a small part of a plant instead of the whole thing.)

Will your grandchildren feel that you have ruined *their* chances to study and enjoy the natural environment? Will they wear gas masks to avoid being poisoned by the foul air? Will their water be undrinkable without elaborate treatment?

Or will we still live in a biosphere that is suitable both for us and for other living things? Will we have preserved the complex, delicately balanced biosphere upon which we depend?

It is impossible to predict the answers to these questions. They depend upon what people value and are willing to work for.

INVESTIGATION 9.1: Some Forms of Pollution

Anything added to the environment that causes harm to living things may be called a form of pollution. Some pollutants are:

1. Chemicals
2. Heat (thermal pollution)
3. Noise
4. Solid wastes (trash and garbage)

One or more of these pollutants may affect parts of the environment, such as air, water, or soil, in your area.

PROCEDURES

A. Each of the teams into which your class has been divided should study pollution in one part of the environment. For example, one team might select air pollution.

B. Prepare a list of the different kinds of pollution in your area. For example, the team that selected air pollution might decide that chemical pollution, noise pollution, and solid-waste pollution all contribute to air pollution. Their list should include the specific kinds of substances causing air pollution. Chemical pollution may include pollution by lead, sulfur dioxide, carbon monoxide, and smoke. The smoke may also contain solid wastes in the form of small particles. Noise pollution may be caused by noise from jet aircraft at or near an airport, from a construction project, from unmuffled motorbikes, from heavy trucks, from chain saws or lawn mowers, and even from loud music.

C. Try to determine where the pollution is coming from. The lead, sulfur dioxide, and carbon monoxide may be coming from the engines of cars, buses, trucks, or heating units. The smoke may be coming from a factory or from burning rubbish.

D. Study the local newspapers. Contact the local government agencies responsible for the control of air quality, water quality, and so forth. Discuss what has been done about pollution in your community. Find out about local or state laws pertaining to local pollution problems that have been enacted

in the past five years. Look also for any evidence of changes in the local problems. Are the conditions that caused the problems improving, remaining the same, or getting worse?

E. Compile all your information in a table similar to the example in Figure 9 • 6.

F. The teams studying water pollution or soil pollution should prepare similar charts.

Figure 9 • 6.

AIR POLLUTION

	Type of Pollution	*Source*	*Community or State Action*	*Status of Problem*
CHEMICAL	Lead	Cars, trucks, buses, etc.	State law requiring anti-smog devices	No change or uncertain
CHEMICAL	Sulfur dioxide	Cars, trucks, buses, etc.	State law requiring anti-smog devices	No change or uncertain
CHEMICAL	Carbon monoxide	Cars, trucks, buses, etc.	State law requiring anti-smog devices	No change or uncertain
SOLID WASTES	Smoke	Factories, rubbish burning	Laws regulating burning	Improving
NOISE		Jets, trucks, local airports, etc.	None	Worse
NOISE		Downtown construction projects	None	No change until projects are completed
NOISE		Motorcycles, chain saws, lawn mowers, etc.	None	Worse
NOISE		Loud music	None	Worse

ANALYSIS

Compare team reports. Which pollution problem seems to be most serious in your area? In what respects has there been improvement? Which problems seem to be most neglected?

INVESTIGATION 9.2: Your Community E.Q.R.

Rating systems of one kind or another are very common to our way of life. A good deal of effort apparently goes into the ratings that proclaim a certain football or basketball team to be "Number One in the Nation." You are certainly aware of the rating systems teachers use to indicate your mastery of a subject.

In this investigation you will use a rating system to indicate the environmental quality of a community. The following procedures explain how your class can determine an E.Q.R. (Environmental Quality Rating) score for your community. The E.Q.R. score will give you some idea of the pollution problems your community may be facing. If your community is fortunate enough to have no form of pollution, its E.Q.R. is 100. If the pollution is mild, the value is between 90 and 99. A score of 80–89 indicates a moderate problem. If the E.Q.R. is below 80, your community has a more severe problem.

PROCEDURES

A. Start with 100 points (a perfect score). Refer to the team charts prepared in Investigation 9.1. You can use these charts to help you make the following environmental-quality ratings. As you consider each form of pollution listed, you should discuss with others in the class what constitutes its particular problems. Also, since it is *your* community that you will be rating, *your* standards are the ones that are important. Copy Figure 9 · 7 in your notebook; use it to record scores as you carry out Procedures B–H.

B. If your community has—
   (1) mild air pollution, subtract 2 points.
   (2) moderate air pollution, subtract 4 points.
   (3) severe air pollution, subtract 6 points.

C. Subtract 1 additional point for each smog alert you had during the last year.

D. If your community has—
   (1) mild noise pollution, subtract 2 points.
   (2) moderate noise pollution, subtract 4 points.

Figure 9 • 7.

	100 points
Air pollution	
Smog alert	
Noise pollution	
Water pollution	
Pollution by factories, utilities	
Soil pollution	
Littering	
Total E.Q.R.	

(3) severe noise pollution, subtract 6 points.

E. Frequently the lakes, ponds, rivers, or sea near a community may be polluted. If the pollution is—
   (1) mild, subtract 2 points.
   (2) moderate, subtract 4 points.
   (3) severe, subtract 6 points.

F. Factories and utilities sometimes discharge heated water into a stream or into the ocean. This may harm the organisms found there. If the pollution is—
   (1) mild, subtract 1 point.
   (2) moderate, subtract 2 points.
   (3) severe, subtract 3 points.

G. An agricultural area frequently becomes polluted by too much salt in the soil or too high a concentration of pesticides and other poisons. If the farms near your community have problems of this kind—
   (1) subtract 3 points if the problem is mild.
   (2) subtract 6 points if the problem is moderate.
   (3) subtract 9 points if the problem is severe.

H. Are there paper and trash in the streets, beer cans in the parks, abandoned automobiles along the roads? If this problem is—
   (1) mild, subtract 2 points.

(2) moderate, subtract 4 points.
(3) severe, subtract 6 points.

ANALYSIS

1. What does the final E.Q.R. indicate about the overall pollution problem in your community?

PROCEDURES *(continued)*

I. Things can and are being done about environmental problems. If you live in a community that is doing something about its problems, it is becoming a better place to live in. Results of community efforts of this type should be publicized so people in other communities can take similar action. To determine an environmental-improvement rating for your community, answer each of the questions in the following list. For each yes answer, credit your community with the number of points indicated.

(1) In the past five years has your community or state passed any laws designed to reduce air pollution? (1 point)
(2) Has there been any measurable improvement in the air in your community in the past year? (3 points)
(3) Has your community or state passed a law pertaining to water pollution in the past five years? (1 point)
(4) Has there been any measurable improvement in the water in the past year? (3 points)
(5) Has your community or state passed a law pertaining to soil pollution in the past five years? (1 point)
(6) Has there been a measurable improvement in the soil in the past year? (3 points)
(7) Have there been campaigns to encourage people to stop littering the streets and parks? (1 point)
(8) Have there been clean-up campaigns? (1 point)
(9) Have there been community attempts to improve the appearance of parks, playgrounds, and beaches in other ways? (1 point)
(10) Are aluminum cans, paper, or scrap metal collected so they can be used again? (1 point)

(11) Do people try to help reduce air pollution and conserve gasoline by driving cars only when necessary? (2 points)

J. Add up the points you have given your community for its effort to reduce and prevent pollution. Rate the score on the following scale:

0 to 7 = Poor
8 to 10 = Average
11 to 13 = Good
14 to 17 = Excellent

ANALYSIS *(continued)*

2. Let us assume there are two communities: The *first* has an E.Q.R. of 90 and a score of 5 in efforts to prevent pollution. The *second* has an E.Q.R. of 80 but a score of 15 in efforts to prevent pollution. In which community would you prefer to live now? Which one would you prefer ten years from now?
3. What are some of the things *you* can do to help prevent or reduce pollution in your community?

Passengers and Supplies

Earth may be compared with a gigantic spaceship moving around the sun. Of course, Earth is far more complex than a spaceship. Everything needed for life is available on Earth—food, energy, air, water, minerals, and soil. One important thing to consider about being in a spaceship is that there is a limit to the supplies that can be carried.

Until recent times, humans were scarce organisms in the biosphere. Their population grew very slowly, and basic supplies were never in danger of being permanently exhausted. But in the last few centuries the human population has increased rapidly—indeed, explosively (Figure 9 • 8). At the same time, the amount of supplies in Spaceship Earth has not increased. True, we have been able to improve our ability to obtain the available supplies. That is why Ohio today supports nearly 11,000,000 people rather than only 15,000. In a spaceship, nothing can be added from the outside. And except for energy from the sun, the same is true of the biosphere.

In the year 1970 it was estimated that Spaceship Earth carried about 3½ billion human passengers. By the year 2000, this load will double if population continues to increase at the present rate. In Section Eight you investigated ways in which populations increase or decrease. At this point you will consider what effects

Figure 9 • 8. Approximate growth of world population.

this increasing population of human passengers may have on our planet's limited supplies.

Consider your need for water. If you have seen large lakes, rivers, or an ocean, it would be hard to believe that water is a limited resource. But it *is* limited. We know that water is vital to life. It is also vital to the way of life we enjoy.

In 1790 there were about 4,000,000 people in what was then the United States. Demands for water were simple: some water was used for drinking, some for cooking, and some for washing. Each person required only a few liters a day, on the average.

In 1900 there were 75,000,000 people in the United States. Each person then required 359 liters (95 gallons) a day, because, for example, there were many new demands for water in industry and agriculture. Actually, each person didn't use 359 liters a day himself, but the way of life required an *average* of 359 liters per person.

By 1950 the population of the United States had risen to 151,000,000 people. There were all kinds of new demands for water: for industry, car washes, modern bathrooms and kitchens, dishwashers, clothes washers, irrigation of farmlands, and so on. People required an average of 522 liters (138 gallons) per person per day!

By 1980 the population of the United States will probably be about 250,000,000, and there will undoubtedly be an increase in the amount of water required per person.

All this means that there is an increasing demand on the part of a growing population of human beings for a resource that is limited. This can be shown in another way if you consider the increase in total water consumption for the period from 1900 to 1980. In 1900 Americans consumed about 28 billion liters (7½ billion gallons) of water per day—in 1980 estimated daily consumption will be 142 billion liters (37½ billion gallons) per day.

We can also look at some other supplies that we citizens of the United States and our way of life demand from Spaceship Earth. Every year each of us uses an average of 10½ kg (23 pounds) of copper, 570 kg (1260 pounds) of steel, 726 kg (1600 pounds) of coal, and 680 kg (1500 pounds) of food. Most nations

of the world don't use resources in such vast quantities.

But what if everyone in Spaceship Earth used supplies at the same rate we do? Considering only copper, this would have meant that the demand in 1970 would have been over 36 billion kg (80 billion pounds). The amount mined in the entire biosphere in 1970 weighed only about 3 billion kg (7 billion pounds)!

Today we are all familiar with the energy crisis. Your community may have experienced shortages of gasoline and heating oil. Local factories may be short of coal. Possibly there were brownouts or even the temporary shutting off of your electric power. Having plenty of energy was something we used to take for granted in the United States; most people thought we would never run out. In 1970, for example, we used twice as much energy as we did in 1950 and 30 times more than in 1850. And the energy we used in 1973 in the United States was *one-third of all the energy consumed* in the entire world! Before 1900 most of our energy came from burning wood; between 1900 and 1950, mostly from coal. At the present time 76 percent of our energy comes from gas and oil, 20 percent from coal, 4 percent from hydroelectric power, and less than 1 percent from nuclear power. Now we are suddenly discovering that for one reason or another even energy sources are limited.

As mentioned previously, the resources in the biosphere are limited. That is to say, the biosphere includes no substance that cannot be used up entirely. Some substances, once used, are lost forever and cannot be reused; others, with careful management, are able to replace themselves. Still others can be used more than once. On this basis, resources have been grouped into three categories.

In the first category are fuels, such as coal, oil, and natural gas, which are considered *nonrenewable* resources. Once these materials are burned, they lose their value as fuels. The second category contains *renewable* resources—for example, living plant material, like timber. We call plants renewable resources because when harvested they can be replaced with other plants. (A vein of coal, once removed, cannot be replaced with another vein.)

The third category includes resources which are termed *re-*

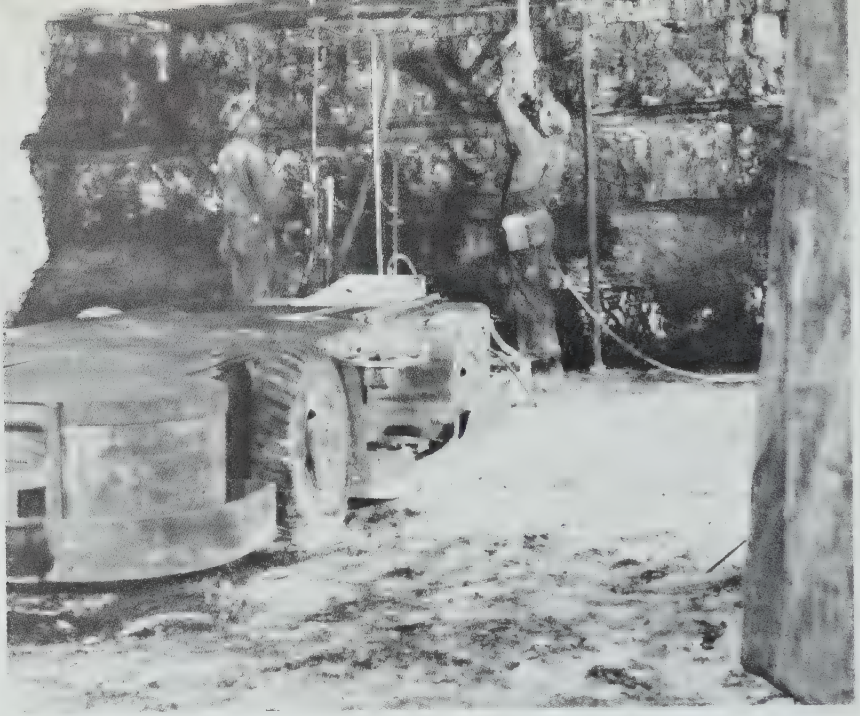


Figure 9 • 9.
A vein of coal being mined. Coal is an example of a resource that cannot be renewed or reclaimed.

claimable. Water, for example, may be taken from a river and pumped through the water system of a city. Much of the same water is released into the city sewage system after use in homes and industry. The used water is, or should be, processed in the city sewage-disposal plant to remove pollutants. This reclaiming of the water is accomplished in some types of sewage-disposal plants by the action of bacteria. They break down the sewage into harmless ingredients—carbon dioxide, water, and various minerals. The purified water, containing these ingredients, is then returned to the river, which carries it downstream to be used in another city. In the few river systems not modified by humans, water is reclaimed by the action of naturally occurring bacteria. Even highly polluted water can be purified to a large extent by nature. When water evaporates, pollutants are left behind. The evaporated water then returns to Earth as rain. Figure 9 • 10 shows how water may be reused along a river.

Junk metals are also classified as reclaimable. Used copper, aluminum, lead, iron, and zinc are among the minerals now being reclaimed for use again.

Something else that is limited in a spaceship is space itself. (You know that a space capsule may have room for only a few astronauts.) But to many people the earth seems so large it will

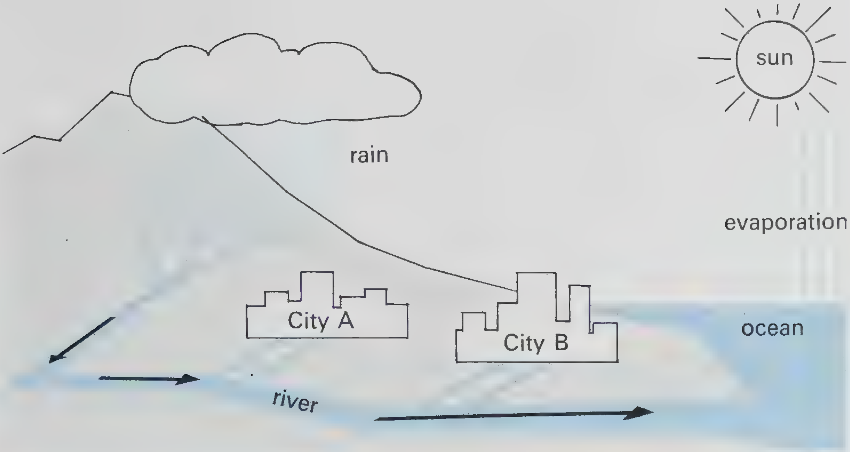


Figure 9 • 10.
City A takes water from the river. Much of the water is purified, returned to the river, and used by City B.

Figure 9 • 11.
This lake—Indian Creek Reservoir, in California—is filled entirely with reclaimed sewage water. The water is not only safe to swim in; it is safe to drink. The sewage-treatment plant that feeds the lake removes almost all pollutants from waste water. Such a plant employs a process that removes (in addition to solid wastes) dissolved minerals that act as nutrients for algae.

never become overcrowded. This is simply not true; parts of it are *already* overcrowded.

Until 1860 the population of the area that made up the United States never exceeded an average of 3 persons per square kilometer. Within 50 years after that, the number of persons per square kilometer increased to 12; and by 1960, to 20. There are, of course, many areas in the United States (for example, the desert regions of the West) where even today there are very few persons per square kilometer. On the other hand, in New York City there are as many as 9650 people per square kilometer. Space throughout the land portion of the biosphere is being increasingly filled up with people, not to mention their belongings and their refuse. India, for example, already has an average of 160 people per

Figure 9 • 12.
Much of the refuse that was once burned or buried can now be recycled and used again.

square kilometer, China 76, and Indonesia 75. Eventually, if the human population continues to grow, the "Standing Room Only" sign will have to be displayed. And at the rate we are throwing away solid wastes—2.4 kg (5.3 pounds) per person per day now, 3.4 kg (7.5 pounds) in 1980, 4.5 kg (10 pounds) in 2000—future generations will have to learn to live on top of a gigantic trash dump.

Perhaps you have come to some of the following conclusions about Spaceship Earth:

1. All supplies on Earth are limited.
2. Space on Earth is limited.
3. Earth can support only so many people, the number depending upon the supplies and space available (carrying capacity).
4. The problem of conserving supplies can be approached in several ways: (*a*) by limiting the number of people using the supplies; (*b*) by reducing the demands on the supplies; (*c*) by recycling or replenishing the supplies, if possible.
5. The problem of maintaining space can only be solved by limiting the number of people occupying the space.

Many thoughtful people have become concerned about the human population explosion. They consider it the biosphere's greatest problem. Think back to your observations in Investigation 9.1 and what you have read since then. Do you begin to understand why these people feel this way?

ON YOUR OWN: Inventing a Water Purifier

Very few people in today's world have sources of pure, clean, untreated water for home or industrial use. People in most places spend a good deal of time, money, and energy in construction and maintenance of water-treatment plants. After water has been used, it must be purified (cleaned) so that other organisms—including other humans—can use it. When water is returned to the natural environment, it should be usable by any organism without causing that organism harm.

What is involved in purifying water? How can muddy water be cleaned? How can harmful chemicals (such as acids and poisons) or disease-causing organisms be removed from water?

Your teacher will give you a sample of dirty water. Try to invent a device that will purify the water. You may want to do some research in the library to get some ideas before you begin. Or you may want to experiment with different ideas of your own. Before you carry out the activity, have your teacher inspect your plan.

Once your apparatus is in operation, decide how you can tell if it is really doing the job. For example, you may want to observe a sample of the purified water under a microscope to see if any organisms are present. You should *not* taste the water to see if your purifier is working efficiently.

ANALYSIS

1. Compare the water that you have purified with water from the tap.
2. Try to account for any differences. You might wish to redesign your purifier.

Benefit and Harm

By now you should understand that humans have a greater impact on the biosphere than has any other organism. This is a result of our large population and the variety of things we do. Can you decide which activities are beneficial and which harmful? In many cases, the decision depends upon your point of view.

If we dam a river to make a reservoir for the production of electric power, this may be harmful to fish and inconvenient for fishermen. But it may be beneficial to people in the area who need electricity for lights and power. If forests are cut down for lumber, this may be harmful to squirrels, birds, and possums as well as undesirable for people who like to hike through forests. And in addition serious soil erosion may result. However, what about the people who enjoy having wooden houses, baseball bats, and books? (Most paper is made out of wood pulp.)

Also, some of our actions in the biosphere are beneficial at the moment but harmful over a long period of time. The use of DDT to kill insects may be immediately useful to a person being bitten by mosquitoes or having a crop eaten by grasshoppers. But the same DDT passes on, in more concentrated doses, into other organisms, such as birds and mammals. There the effects may be harmful. Some scientists think that certain birds fail to reproduce because DDT in their bodies reduces the thickness of the shells

Figure 9 • 13. A crop duster sprays beans to control insect pests.

enclosing their eggs. Such thin shells often break when the parent birds sit on the eggs, or the eggs may simply dry up. The existence of some of our rare and beautiful birds—bald eagles, ospreys, and pelicans—is endangered in this way (see Figure 10 • 2).

Through irrigation, we bring water into dry areas to grow more and better crops; this is almost immediately beneficial. But what if prolonged use of mineral-rich irrigation water turns farmlands into salt flats? This is happening now in our own Southwest; it has happened in the past in Southwest Asia.

Much of our effect on the biosphere is the result of our efforts to earn a living. For example, dirt, smoke, and chemical fumes

Figure 9 • 14. Accumulation of mineral salts in an irrigated valley. Notice that few plants can survive this condition.

from factories and power plants pollute the air. Many workers would be without jobs if the factories were shut down. Many more could not make their living without the power from the power plants. In some circumstances, electricity from a power plant may actually be necessary to keep people alive. Shall we decide that air-polluting industries are beneficial or harmful?

INVESTIGATION 9.3: Judge and Jury

No law can prevent polluted water from killing fish or pollutants in air from killing trees. Citizens and governments can, however, make decisions and pass and enforce laws to prevent water pollution and air pollution, thus protecting many forms of life, including ourselves. This investigation will give you a chance to make some value judgments. Your judgments should be based upon class discussion of evidence about people's interactions with the biosphere. In making the judgments, you should discover that there are at least two sides to every question.

Figure 9 • 15. An oil refinery. In such an activity as refining, it is often difficult to judge between the immediate good to society and the potential, long-range harm to our environment.

PROCEDURES

Select several environmental cases from the following list of suggestions. If possible, choose cases showing similarities to environmental situations in your own community. For each case there should be a student who presides as judge. Another should act as a "defense lawyer" who presents the case in favor of the human

activity affecting the environment, and still another should be the "prosecution lawyer" who presents the case against the activity. In addition, each "lawyer" can designate several students as witnesses. Witnesses should look up information about aspects of the particular situation before the "hearing." The rest of the class can serve as the jury. Ordinarily, a jury would not discuss a case in public, but in this situation the jury members' discussion should prove to be an interesting part of the proceedings. At the completion of the jury's deliberations, each jury member should write a brief opinion and deliver it to the judge, who will make the opinions public to the entire class.

Suggested Cases for Environmental Hearing:

1. Building an airport for supersonic jets in your area.
2. Developing offshore oil drilling in an ocean-resort bay.
3. Converting a local river into a multiple-use reservoir.
4. Building a paper-pulp mill in your area.
5. Removing trees and channeling (straightening) a river.
6. Developing a limestone quarry on a wooded hillside.
7. Clearing native trees and shrubs to establish grassland for livestock grazing.
8. Building a nuclear power plant on an ocean bay.
9. Using pesticides to control mosquitoes in a suburban area.
10. Using chemicals to kill vegetation along roadways.
11. Building a uranium-processing mill along a river.
12. Building a cluster of high-rise apartments around a city park.
13. Creating a solid-waste dump in a rural area to take care of trash and garbage from a nearby city.
14. Using atomic explosives to create an ocean-side harbor.
15. Cloud seeding to produce rain in a semiarid region.
16. Using DDT to control Dutch elm disease in your town.
17. Building a nerve-gas testing site in an isolated desert area.
18. Passing a community regulation banning burning of trash.
19. Diverting a river's course so that the river empties into the Mississippi River rather than into one of the Great Lakes.
20. Passing a regulation that would limit the number of chil-

dren for whom income-tax deductions could be claimed.

21. Introducing Old World wild sheep into semiarid desert-mountain country in our Southwest.
22. Constructing a sea-level saltwater canal across Florida from the Atlantic Ocean to the Gulf of Mexico.
23. Setting up strict pollution-control regulations for all local industries.
24. Setting aside an extensive acreage of naturally vegetated open-space land for a county park.
25. Lowering air-pollution standards so that a local power plant can use low-grade coal to produce cheaper and more abundant electrical power.

Introduced Animals and Plants

When people make changes in the biosphere—alter ecosystems—they do not necessarily destroy all other living organisms. Instead, new habitats may be created into which certain native species can move. In addition, organisms that have been introduced from other countries may get along very well in the new habitats.

Among the most widespread human changes in the biosphere are our many cities (urban ecosystems) where natural ecosystems previously existed. Cities have existed for centuries in Europe and Asia but are much more recent developments in North America. Hence, there has been less time for native American animals and plants to become adapted for living with people in cities. Old World animals and plants have had a long time to adjust to urban life. One should not be surprised to find that the animals or plants that live in our cities are usually the Old World species. They have been introduced from Europe and Asia.

Three species of birds from Eurasia have become established in American urban areas and other places where people live, such as farms. These species are: the English, or house, sparrow (pages 197–199 and Figure 8 • 22); the starling; and the rock dove, or domestic pigeon. The first English sparrows were introduced from England into New York City in the 1850's. Starlings were introduced in 1890 by a person who wanted to bring into the United States all of the birds mentioned in Shakespeare's plays. No one knows when the first pigeons were brought to America from

Figure 9 • 16. Starling.

Figure 9 • 17. Rock dove, or domestic pigeon.

Europe, but it was probably by the early colonists. Today, these three birds occur commonly—often too commonly—in human-impact areas in all 50 states. You can obtain a rough measure of the human impact in an area by determining the relative abundance of these three birds as compared with the native species (robins, blue jays, crows, mockingbirds, house finches, blackbirds, chimney swifts, and so on). Fewer native species in relation to the three Eurasian species usually indicates a greater human impact and a more urbanized area.

FOR CLASS DISCUSSION

The following are counts of birds made on three dates along the same section of a country road through grassland. Road-mileage readings are on the left of the birds' names; the number of individuals seen at each date is on the right. Based upon the species of birds present, explain what kind of habitat might be located at Mile 7.2. (Note: horned larks, meadowlarks, and vesper sparrows are characteristic of grassland and agricultural land.)

Figure 9 • 18.

Miles	*Jan. 12*	*Jan. 28*	*Oct. 2*
1.0			red-tailed hawk: 1
1.3			ferruginous rough-legged hawk: 1
1.6			vesper sparrow: 1
3.4	horned lark: 1		
4.1	American magpie: 2		
5.7	American magpie: 1		
5.8		horned lark: 1	
6.0			sparrow hawk: 1
6.6		rough-legged hawk: 1	
7.2	English sparrow: 35 rock dove: 4 starling: 15 meadowlark: 1 horned lark: 15 American magpie: 1	English sparrow: 16 rock dove: 3 starling: 22 American magpie: 4 pigeon hawk: 1	English sparrow: 12 starling: 1
7.3	meadowlark: 1		
7.4	American magpie: 6 great horned owl: 1		
7.5	American magpie: 1		
7.6	meadowlark: 1		
9.4			white-rumped shrike: 1 sparrow hawk: 1
11.2		horned lark: 2	
11.3		horned lark: 1	

Extending Your Knowledge: Man-Nature Case Histories

Case I: The Disappearing Lake

High mountain lakes may be beautiful, but they seldom support many large fish. An ecologist, interested in improving fishing in a high mountain lake, decided to make more fish food available, so that there would be more and larger fish. As an experiment, he dumped fertilizer into the lake one summer. This encouraged the growth of plants, which in turn encouraged the growth of insects, which in turn encouraged the growth of the fish. By summer's end, there were so many plants in the lake that it looked green from the air rather than blue like the surrounding lakes. (These other lakes were the controls.)

The experiment seemed to be successful, so the decision was made to fertilize more of the high lakes the next summer. However, when the ecologist flew over the lake country early the next season, he was unable to find his green lake. Eventually he did locate the lake, but it was blue again. In fact, the plants, insects, and fish were much less abundant than they had been before the lake was fertilized. What do you think might have happened in this interaction of people with nature?

CLUES:
1. During the winter, there were low temperatures and heavy snows.
2. During the summer season, the abundant aquatic plants, through photosynthesis, provided not only food but oxygen for other forms of life in the lake.
3. Both plants and animals used oxygen to obtain energy from their food.

Case II: Eastern Maples in the West

A house builder in the West decided to establish a new housing development in a dry grassland. Before constructing any houses, he planted about 400 eastern maples as shade and ornamental trees along the main road. A big sign then went up announcing the sale of lots in "Maple Estates." No houses were built until a few years later. When the subdivision was finally completed, it was no longer called "Maple Estates." Why?

CLUES: 1. The precipitation in this grassland area is about 14 inches a year.
2. The species of maples planted is a native of eastern deciduous forests, where the precipitation may exceed 30 inches a year.
3. Most of the deciduous trees in the dry grassland are found along rivers.

Case III: Detergents and Oil

An oil tanker broke up at sea, discharging much of its cargo into the water. Eventually the oil washed up on nearby beaches, destroying many of the marine organisms there. To get rid of the oil, a detergent was successfully employed. However, the detergent proved to have a longer and more harmful effect on living things than did the oil. Why?

CLUES: 1. Both oil and detergents are harmful to many marine organisms.
2. Over a period of time, oil can be broken down through the activity of certain organisms.
3. Like oil, some detergents can be broken down by organisms; but other detergents cannot.

Case IV: Starfish and Oysters

Along the East Coast, starfish were destroying large quantities of oysters. The oyster fishermen decided to try to get rid of the starfish. They went out in their boats, dredged up the starfish, chopped them up into pieces, and dumped them back into the ocean.

For a while the oysters flourished. But in a short time there were more starfish than ever before, and the oysters had almost disappeared.

CLUE: Starfish have the ability to regrow missing parts of their bodies.

Case V: Coyotes and Jackrabbits

In an area of the Southwest, ranchers decided that coyotes were killing off some of their sheep. They organized several large coyote hunts and pretty well eliminated coyotes from the region. Within a few years there were jackrabbits everywhere, destroying

crops and grass on the rangeland. What do you think might have happened to cause this problem?

CLUES: 1. Jackrabbits are vegetarians.
2. Coyotes eat rabbits and other small animals.

Case VI: About a Movie

A government agency was concerned about saving a stand of timber that was being attacked by insects. Pesticides were used to destroy the insects. Since the area was a nature preserve, the agency thought it should explain to the public why it used the pesticides. Consequently, a special motion picture was produced, telling about the insects' harmful effects, about the need for use of pesticides, and about how carefully the pesticides had been applied from airplanes. Furthermore, the movie narrator commented, the pesticides killed only the insects, and thus no other wildlife was affected. How would you react to this?

CLUE: Many insects eat vegetation, and many birds eat insects.

SECTION TEN

Reproduction

Individuals in the biosphere must solve many problems just to stay alive. Individual plants and animals must obtain and use food. To be used, food must be transported throughout the body and distributed to cells. Wastes must be eliminated. And all the body systems must co-operate if the organism is to live.

But no matter how well it solves the problems of getting along in the biosphere, every individual dies. This means that some individuals of a species must successfully reproduce or that species will not survive.

For example, biologists are concerned about the future of the California condor—one of the largest flying birds alive. At the last count, only about 50 California condors were known to be living. Though these giant birds are protected by law, people sometimes shoot them. Also, some die of disease or old age, and, in addition, their habitat is in danger of being destroyed. Will the number of young condors hatched and surviving within the next few years be greater than the number that die within the same time? The answer to this question is as yet unknown. But if the answer is no, the California condor will disappear forever from the biosphere. This is true of other species, too. Some biologists estimate that more than 100 species of animals in the United States alone now face extinction.

The reverse of extinction may occur when births greatly exceed deaths. The result then is *overpopulation*, which eventually may prove to be almost as disastrous. Some examples of overpopulated species are rabbits in Australia, deer in some parts of the United States, various kinds of insects in farm areas, rats in some of our cities, and people in some areas.

Overpopulation of a species in nature, though causing temporary hardships, is usually brought under control. Imagine what our or any other organism's life would be like if any one kind of organism—mice, for example—reproduced without any natural control. There would no longer be space on Earth for any other organism. It has been estimated that if the common housefly

Figure 10 • 1. Locusts are found in many parts of the world. What other organisms might be affected by a population explosion of locusts?

were allowed to reproduce unchecked, flies would cover the earth to a depth of several feet in less than five years! Why doesn't this happen?

It doesn't happen for several reasons—all of them unpleasant for individuals of the overpopulated species. Their food or water supply may run out. They may be poisoned by their own wastes. They may be so crowded together that they begin battling for food and space. Or several of these things may combine to reduce the population size.

We are in the midst of a population explosion in our own species. You may have heard predictions that if our population continues to grow at the present rate, eventually there will not even be standing room for all the people of the world. But if you stop to think about these predictions, you will realize that such a situation is impossible. Before we reach that stage of crowding, famine, pollution, war, or disease is likely to reduce our numbers. In spite of our knowledge and technical skills, we are controlled by checks and balances similar to those which control other living things. One American scientist has said that if we do not learn to control the size of the human population, then nature will control it for us.

Figure 10 • 2. Human activities have placed many organisms in danger of extinction. The effect may be indirect, as in interference with normal reproduction, the case with the California condor and the brown pelican. Or the effect may be direct, as in the killing of wolves or whales.

Above: A California condor. Condors will not reproduce if their nesting sites are disturbed. In a once vast area, only *one* remote valley remains for nesting.

Left and below: A brown pelican and a crushed pelican egg. Chemicals such as pesticides in the birds' diet may weaken the shells. When the adult sits on the eggs to incubate them, the shells are crushed.

Above: Wolves are an endangered species, but we still find scenes like this.

Below: The great whales are being killed more rapidly than they are being born. Some species are already extinct. Others will soon be if the current overkilling continues. If the nations of the world could agree, the number of whales harvested each year could be related to the number being born. With careful management, the whales need not become extinct but could be treated as a crop for human use.

Asexual Reproduction

The two basic methods of reproduction are asexual and sexual.

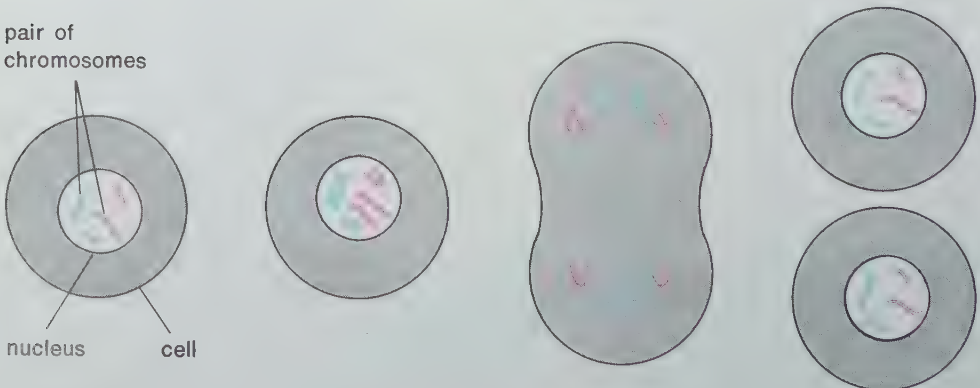
The asexual method of reproduction does not involve the two sexes, male and female. In the most common type of asexual reproduction, part of the body of the individual is split off. The separated part is able to grow into a complete individual. Figures 10 • 5 and 10 • 6 illustrate asexual reproduction.

Of course the part separated must have the ability to produce all the structures of the complete individual. To understand how this is possible, we must observe what happens when a cell divides. Some cells are very complex, yet they can divide into two cells, called daughter cells. Each daughter cell eventually becomes like the original cell. This is remarkable. Can you think of any complex structure, such as an automobile, watch, or radio, that can be divided in half in such a way that each half will have the structure of the whole?

Cells are able to divide into identical daughter cells for this reason: The way a cell is built and behaves is controlled by

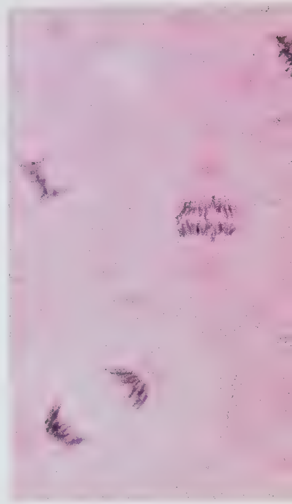
Figure 10 • 3.
Cell division.

1. A cell with four chromosomes, or two pairs. Division has not yet started.
2. Each chromosome makes another like itself. The cell now has eight chromosomes.
3. The eight chromosomes separate into two groups of four, and the cell begins to pinch in the middle.
4. Now there are two cells. Each cell has the same kind and number of chromosomes as the original cell.



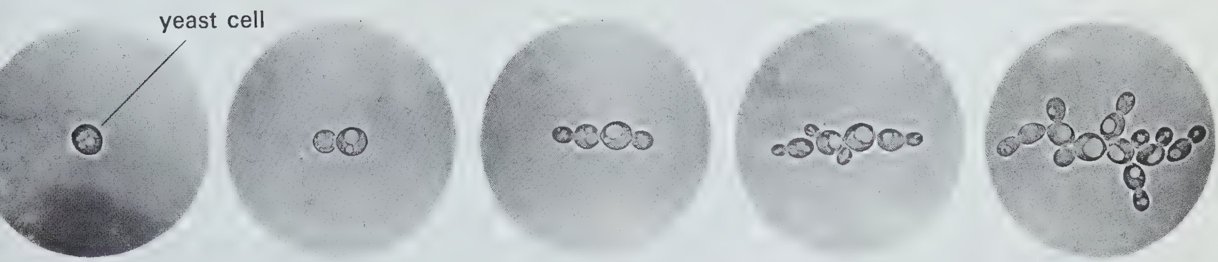
chromosomes, structures in its nucleus. (If the nucleus is removed, the cell will die.) Each daughter cell receives a set of chromosomes like those of the parent cell. Figure 10 • 3 illustrates this important process. Shortly before the cell divides, each chromosome makes another like itself. This process doubles the number of chromosomes in the cell. The cell then begins to divide. As it divides, the chromosomes are divided into two equal groups. Each daughter cell gets one of these groups. Each will have the same number and kind of chromosomes as the parent cell.

Figure 10 • 4. Animal cells dividing.



Single-celled organisms, such as yeast cells (Figure 10 • 5) or protozoans, divide by cell division. This is a form of asexual reproduction. This same process of cell division occurs in the development of organisms that are composed of many cells.

Sometimes, for example, a large part of the body of a hydra (Figure 10 • 6) splits off. Each of the cells in the part has a complete set of chromosomes, and so, after several cell divisions, a new organism, identical to the parent, develops.



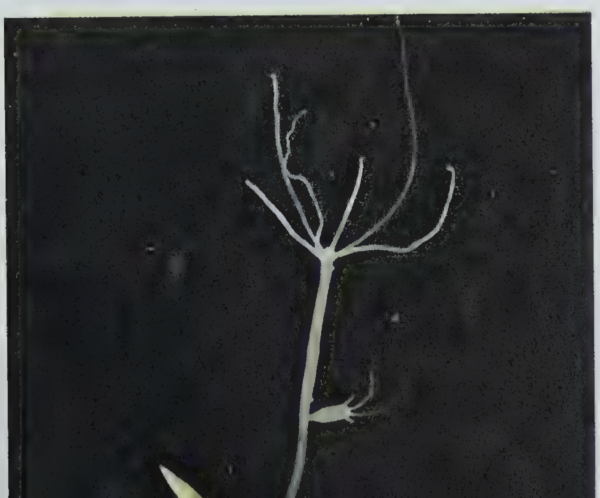


Figure 10 • 5. In five hours, one yeast cell produced the results pictured in the row above. How many divisions are necessary to produce all the cells shown in the figure at the far right?

Figure 10 • 6. Budding hydra attached to a water plant.

INVESTIGATION 10.1: One Potato, Two Potato

Many organisms, such as starfish, can be cut in half; each half grows into a whole individual. This is a type of asexual reproduction. You can see another example of asexual reproduction by examining slices of Irish potato.

MATERIALS

White (Irish) potato
Aluminum pie pan
Planting-soil mix
Blotter or paper toweling
Piece of cardboard, large enough to cover the pan

PROCEDURES

A. Fill an aluminum pan with planting-soil mix to a depth of about 2.5 cm. Thoroughly moisten the soil.
B. Cut off a small piece of the white potato. Be sure that the slice contains two or three eyes. Cut a second potato slice that does not contain eyes.
C. Place both potato slices on top of the wet soil. Cover each slice with a piece of wet blotter paper (or wet paper towel), and cover the pan with cardboard. Add enough water to the blotter every day or so to ensure that the potato slices stay moist. Keep them in a cool place.
D. Observe the potato slices each day. Record your observations in your notebook.

ANALYSIS

Did either slice show signs of asexual reproduction? If so, explain how this happened.

Sexual Reproduction

In sexual reproduction two individuals, or at least two different reproductive elements, are involved. A cell from a male combines with one from a female to become a single, new cell. This cell divides many times to form an *embryo* (a new individual that has not yet been born or hatched). The specialized reproductive cells produced by parents are called *gametes*. Gametes produced by males are called *sperm cells*. Those produced by females are *egg cells* (Figure 10 • 7).

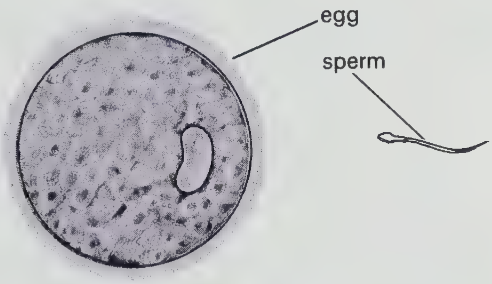


Figure 10 • 7.

Eggs develop in organs called *ovaries*. In mammals, the mature egg leaves the ovary and enters an *oviduct*. The oviduct is a tube that leads to the *uterus*, a structure where the embryo develops. In the mature human female, an egg is normally produced and released about once every four weeks.

Sperm cells are formed in the *testes* of male animals. In humans and most other mammals, the testes are in a pouch (the *scrotum*).

Different species use different methods to allow the eggs and sperms to unite. The union of egg and sperm is called *fertilization*. An important difference between methods of fertilization has to do with whether the fertilization is *internal* (occurring inside the female) or *external* (occurring outside).

In many animals that live in the water, fertilization occurs externally. The female releases eggs into water. The male then deposits sperms near the eggs, and the sperm cells move to and fertilize the eggs. Salmon, for example, lay their eggs in sand or

Figure 10 • 8.
Chick embryo after about two days of incubation.

gravel in shallow water. The eggs are often laid in scooped-out areas or in depressions, so they are somewhat protected. The male fish deposits its sperms close to the eggs at about the same time that the eggs are laid. There is no danger of the egg or sperm cells drying out, because they are in the water.

Land-dwelling animals have a problem, for sperms must reach eggs by swimming in some kind of fluid. Since it is impossible for sperms to swim on dry land, land-dwelling animals rely on internal fertilization. During internal fertilization, a fluid containing sperms is introduced into the female, and a sperm unites with an egg.

The embryos of most organisms develop at the temperature of their surroundings. The embryos of birds and mammals, however, require warm and nearly constant temperatures.

Adequate temperature is maintained in a number of ways. For example, consider chickens. Once a chicken egg has been fertilized, it develops to a certain stage and is then laid. (Normally, the eggs you buy in the market have not been fertilized.) But if a fertilized egg were left unattended and if the temperature dropped, the embryo would die. Chickens avoid this possibility

Figure 10 • 9.
A. Incubation is necessary for most bird eggs.

B. Snake and eggs.

by sitting on the eggs to keep them warm (incubation) until the eggs are ready to hatch. Some snakes and lizards also incubate their eggs. Others lay their eggs in warm soil; and still other kinds repeatedly warm themselves in the sun and then curl around the eggs.

In some animal species, fertilized eggs are retained in the females until they are ready to hatch. This is true of rattlesnakes, garter snakes, and water snakes. The young are "born" inside the mother and leave her as young snakes—not eggs. In this way even more protection is provided for them.

The most intensive care of the young is seen in *mammals*, animals that give milk to their young. In mammals, young are nourished by the mother both before and after they are born.

If sperm cells are introduced into the birth canal of a mammal and move through the uterus to the oviduct at a time when an egg is there, fertilization may occur. The fertilized egg begins to divide, and eventually a large number of cells are produced. This is the beginning of the life of a new individual. After several days the embryo moves into the uterus, where it attaches to the uterine wall. Blood vessels leading from the embryo develop, and these

Figure 10 • 10. Mammals provide food and protection for their young.

Figure 10 • 11.
A drawing showing an unborn baby, the bag of fluid which protects it, and the placenta through which it is nourished. The umbilical cord has blood vessels that carry the embryo's blood to the placenta and back.

entangle with blood vessels in the wall of the mother's uterus. This association of the vessels of mother and embryo forms the *placenta* (Figure 10 • 11). Food and oxygen from the mother's blood pass through the placenta into the embryo's blood. The placenta is also the place where the embryo's wastes are eliminated. They pass from the embryo's blood into the mother's blood—to be removed by her lungs and kidneys. Not only is the unborn individual nourished by the mother, but it also floats in a bag of fluid (Figure 10 • 11), which protects it from physical damage.

The real significance of sexual reproduction lies in the combination of chromosomes—the father's chromosomes contained in a sperm and the mother's in the egg. The union of the sperm with the egg results in a *zygote* (fertilized egg), which has chromosomes from both father and mother. Through cell division the zygote eventually forms all the intricate structures that characterized its parents. A great deal of knowledge is available about how chromosomes behave and how characteristics are passed on from parent to offspring, but much still remains to be discovered.

FOR CLASS DISCUSSION

1. Water-dwelling animals often produce great numbers—perhaps hundreds or thousands—of eggs. Land-dwelling animals

usually produce fewer eggs. How might you account for this difference?

2. In what way do you think organisms produced by sexual reproduction might differ from those produced asexually?
3. Can you think of one or more kinds of water-dwelling animals in which internal fertilization occurs?
4. Human body cells have 23 pairs of chromosomes (a total of 46). The offspring of two parents, each with 23 pairs, will also have 23 pairs. This is true of the fertilized egg and each body cell of the new individual that develops. What do you think must happen in the production of sperms and eggs to ensure that each body cell of the offspring contains only 23 pairs of chromosomes?

Extending Your Knowledge

Several years ago the cattle raised in the southeastern portion of the United States were severely infested with larvae (a wormlike insect developmental stage) of the screwworm fly. The larvae develop from eggs that the female fly deposits on the skin of cattle. As the larvae grow, they eat through skin and muscle tissue. The result is often an ugly, open skin wound that invites secondary bacterial infection. The infected animals often die.

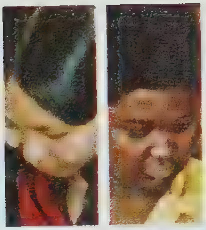
Spraying the cattle with pesticides was tried but proved ineffective. Agricultural scientists then decided to try something else. They knew that the female screwworm fly mates only once and stores the sperms from the mating in her body. As she lays each egg, sperms are released to fertilize it. Although the female only mates once, the male may mate with many females. How might these facts be used to control the fly?

The scientists raised thousands of screwworm flies in the laboratory. The males were exposed to large doses of X rays. This radiation caused them to become *sterile* (caused the reproductive capability of the sperms to be destroyed). Yet it did not reduce their ability to mate. During the next two years, these sterile males were released into the natural population. The results were dramatic. The population of flies was reduced to the point where they were no longer a serious problem for cattle ranchers.

Discuss the way in which the population of screwworm flies was reduced. Do you think sterilization of males would be effective in controlling populations of other kinds of organisms?

SECTION ELEVEN

Genetics



The young of dogs are puppies, never kittens. We are all so familiar with this fact that we may forget how wonderful and mysterious it is. Generation after generation, the offspring of two organisms tend to resemble their parents and each other. We have all seen pictures of men and women who lived in the past. They might be dressed in unfamiliar clothing, but there is no doubt that they were much like men and women of today.

Individual organisms of the same species are *similar* in most of their features. It is also true that organisms of the same species are nearly always *different* in some of their features. The study of what causes such similarities and differences is called *genetics*. You can begin a study of genetics by observing members of your class.

INVESTIGATION 11.1: Comparing Individuals

The members of your class will differ in many respects, such as height, weight, facial appearance, hair color, and eye color. The differences are great enough so that you can easily recognize each individual.

We will select a few characteristics to study to obtain information about similarities and differences among individuals.

MATERIALS

Graph paper
Meterstick

PROCEDURES

A. Look carefully at the eyes of each member of your team. Arrange the members of the team in a line according to how dark their eyes are—the near blacks and dark browns at one end, then the hazels, and finally the blues.
B. Now try to arrange all the members of your class according to the color of their eyes.

ANALYSIS

1. Do any members of your team have *exactly* the same eye color?
2. Do any members of your class have exactly the same eye color?
3. How do your answers to Questions 1 and 2 compare with each other? If there is a difference, how can you explain it?

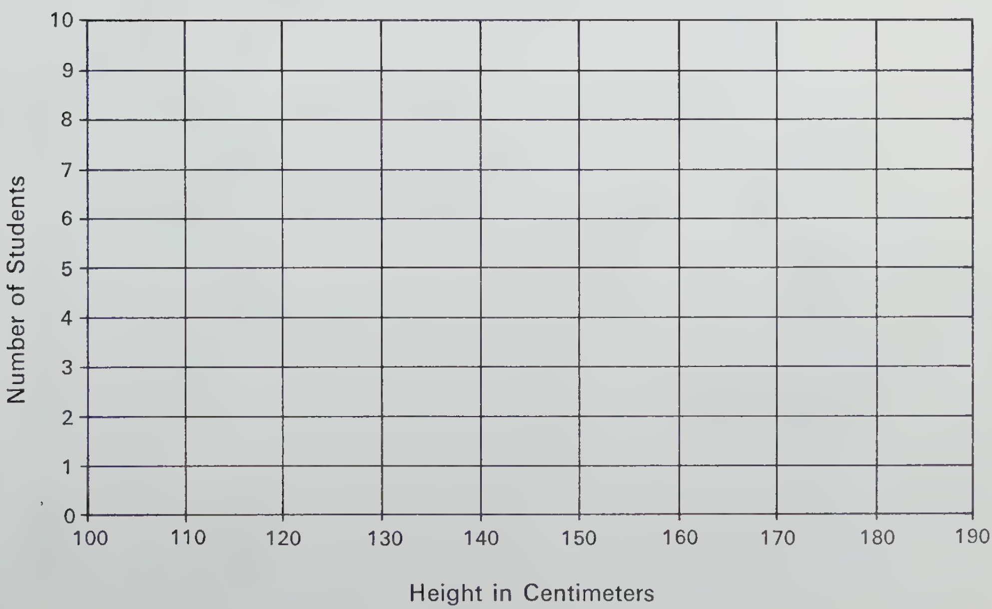
PROCEDURES *(continued)*

C. Measure and record the height of each member of your team.

D. Combine the measurements from all teams on the board. Group heights in 10-cm ranges. For example, you may wish to start at 100 cm. One set ranges from 100 to 109, the next set is 110–119, and so forth. Beside each set record the number of students whose height falls in that set.

E. Label a piece of graph paper as in Figure 11 • 1. Now plot the class data on the graph. For each set, draw a dot *between* the vertical lines representing the top and bottom of the range. For example, if there are two students in the 130–139

Figure 11 • 1.



group, make a dot where horizontal line 2 and vertical line 134 meet.

F. Draw a line connecting all the dots.

ANALYSIS ***(continued)***

4. What is the average height of the students in your class?
5. What relationship exists between the graphed data on student height and the average height?

Inheritance

Our previous discussion and observations have suggested that:

1. Offspring resemble their parents.
2. Offspring do not resemble their parents *exactly*.

You are also well aware that:

3. Offspring of the same parents may differ greatly from one another. Some are males and others are females. Among children of the same sex there will be many other differences.

How can we account for these observations? We may say that the characteristics of the offspring are the result of "something" they *inherit*. But that is not really an explanation.

People have been interested in inheritance for a long time. They want to know about themselves—why they are male or female, why their eyes are blue or brown, why cancer or some other disease seems to "run in the family," and so on. They also want to know about inheritance so that they can develop better plants and animals: plants that produce more food or fiber or that are better able to resist plant diseases, and animals that produce more meat, eggs, milk, or wool.

Let us think about what we inherit from our parents. That is, what do we receive from our parents that makes us what we are? In the section on reproduction you learned that each of us begins

Figure 11 • 2. Longhorn cattle, showing differences in color.

life when an egg, which is produced by the mother, is joined with a sperm, which is produced by the father. So we know that:

4. The "something" people inherit could be in either the egg or the sperm, or in both.

We all have observed that a child may be like its mother in some ways and its father in others. This seems to indicate that:

5. The "something" people inherit is probably in both eggs and sperms.

In human beings and other mammals, early development of the embryo takes place in the uterus of the mother. Thus, there is a possibility that the developing embryo will be influenced by the mother during this period. In many other animals, such as the frog, the eggs and sperms are shed in water. An egg and a sperm unite, and the frog embryo is on its own. The parents never have any contact with it again. Therefore:

6. In some animals the only link between parents and offspring is the egg and sperm.

In these animals, therefore:

7. *Everything* that is inherited must be in eggs and sperms.

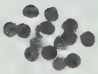


Figure 11 • 3. Each one of these tiny eggs, once fertilized, contains all the information necessary for it to grow into an adult frog.

Scientists have made many observations of and experiments on all sorts of organisms that lead to the general conclusion:

8. In all organisms the eggs and sperms contain everything that is inherited.

Eggs and sperms contain numerous microscopic parts. It has been discovered that inheritance is associated with one of these microscopic parts—the chromosomes (Figure 11 • 4). Chromosomes are found not only in eggs and sperms; all body cells except red blood cells contain chromosomes.

It has also been discovered that in each species, individuals nearly always have the same number and kinds of chromosomes. Except for gametes, each of the body cells normally has 46 chromosomes. These are not 46 different kinds of chromosomes, however. Actually there are only 23 kinds, but there are 2 of each kind. In most frog species each cell has 26 chromosomes, but only 13 different kinds. A dog cell has 2 each of 39 kinds, to make a total of 78.

Many experiments have been performed showing that there is not just one "something" in the chromosomes that is responsible

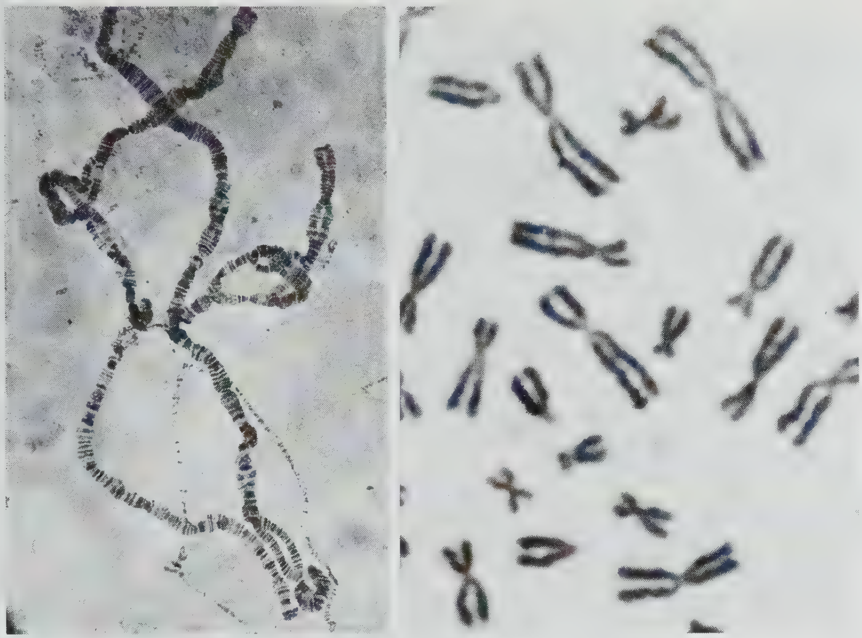


Figure 11 • 4.
Left: Fruit-fly chromosomes. In certain cells the chromosomes are very long. When the cells are stained, dark bands appear on the chromosomes. Each dark band may represent a gene or group of genes.
Right: Some human chromosomes. Why do you think they are double?

for inheritance. Instead, there are numerous different "somethings," known as *genes*. Each gene is responsible for some small effect. You have genes that control the color of the cells in the iris of your eye. There are many different kinds of genes that affect the color of your skin. There are genes that control the formation of the molecules of which your body is composed. Indeed, what you are is determined by the way all of your genes act together. There are genes in plant cells that control the formation of chlorophyll. In fact, practically every structure, function, and activity of an organism is controlled by, or at least influenced by, genes.

Every gene is carried by a particular kind of chromosome, and each kind of chromosome carries many different kinds of genes. Thus a gene that influences the color of your eyes is carried by one of the 23 kinds of chromosomes. But remember that you have 2 of each kind. Therefore, each of your cells will contain 2 of these genes that influence the color of your eyes.

In Investigation 11.1 you saw how much height and the color of eyes can vary. This is because many different kinds of genes in-

fluence eye color and many different kinds of genes influence height. Not only are there many genes that influence the color of eyes, but each kind may occur in different forms. For example, one of the eye-color genes exists in at least two forms. One form is involved in the production of brown pigment. In the other form of this same kind of gene, no brown pigment is produced and the eyes are blue.

These different expressions, or forms, of the same gene are called *alleles*. Thus, this eye-color gene has a brown-eye allele and a blue-eye allele.

You can better understand how different alleles are inherited by carrying out Investigation 11.2. Before you begin, here is a summary of the most important things that have been said about inheritance:

1. Everything that an organism is (its structure) or does (its function and behavior) is controlled or is influenced by genes.
2. An individual's genes are inherited from its parents.
3. The genes are located on chromosomes. Each chromosome has many different genes, but usually only one of each kind.
4. Thus, since there are only 2 chromosomes of each kind in a cell, there can only be 2 genes of a particular kind in a cell.
5. Each kind of gene may have different forms, or alleles. But each cell can have only two alleles for the same gene. Thus, a cell might have two brown-eye alleles, two blue-eye alleles, or one brown-eye allele and one blue-eye allele.

INVESTIGATION 11.2: A Model for Inheritance

Chromosomes and the genes they carry are inherited in a highly exact manner. We can learn something about how this occurs by using chips to represent the genes.

MATERIALS

Chips, all of the same color, 4
(or squares, 5 cm x 5 cm)
Glass-marking pencils

PROCEDURES

A. Assume that each of the chips represents a gene for eye color. The cross we shall consider will be between two people having blue eyes, and in genetics the blue-eye allele is represented by a **b.** Using the glass-marking pencil, mark all the chips with a **b** (not a capital letter). Mark each of two chips with a ♂ (male) sign and each of two with a ♀ (female) sign.

B. Put two chips marked ♀ on the table together to represent the two alleles for blue eyes in the body cells of the mother. Put the other two, with the ♂ sign, together to represent the two alleles in the body cells of the father.

C. When the cells in the ovary of the mother develop into eggs, a complicated change occurs. One of the main results is that the number of chromosomes is reduced one-half. Remember that a human cell has 46 chromosomes. These are not all different. Actually there are 23 different kinds of chromosomes, but there are 2 of each kind. When a mature egg cell is formed, it contains just one of each of the 23 kinds of chromosomes. The same sort of change occurs when the sperm cells are formed. Move one of the ♀ chips to a place by itself to represent a mature egg cell.

D. Let a ♂ chip represent a mature sperm cell.

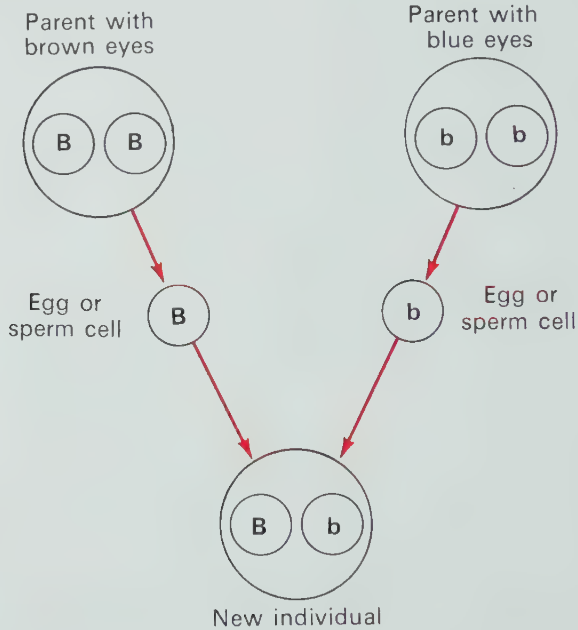
E. Now, move the "egg" and "sperm" chips together to represent fertilization.

ANALYSIS

1. What color eyes will the offspring have?
2. How many **b** alleles can one normally pass on to his or her offspring?

Next, consider what the eye color of a child might be if one parent has brown eyes (**BB**) and the other parent has blue eyes (**bb**). Study Figure 11 • 5.

Figure 11 • 5.



Notice that the new individual has one allele for blue eyes (**b**) and one for brown (**B**). What will the eye color of such an individual be? Geneticists have found that when a cross of this sort is made, the **Bb** individual's eyes are nearly always brown. A single allele for brown eyes causes the production of enough brown pigment to make the eyes brown. For this reason, we say that the allele for brown eyes (**B**) is *dominant* over the allele for blue eyes (**b**). The allele for blue eyes is said to be *recessive.*

In most pairs of alleles, one is dominant and one is recessive.

Now, suppose that brown-eyed parents with **Bb** alleles have children.

PROCEDURES (*continued*)

F. Mark each of two chips with a ♀. Also mark one of these with a **B** (for the brown-eye allele) and the other with a **b** (for the blue-eye allele). Mark each of the other two chips with a ♂. And also mark one of these with a **B**, the other with a **b.**

G. Arrange the chips to represent eggs that the female parent can produce and sperms that the male parent can produce.

H. Group the chips in all the ways they can possibly unite to form a new individual. Record the possible combinations.

ANALYSIS (*continued*)

3. List the possible combinations of alleles together with the eye colors they would cause.

A Genetic Checkers Game

An easy way to see what will happen in a **Bb** × **Bb** cross is to use a *genetic checkerboard.* Make a chart like the one below and try to fill in the blanks and to determine what the eye colors will be. When you have finished, turn to page 280 and check your results.

Each square on the checkerboard represents one type of individual. Consider first the "square" labeled "Individual 1." The

Figure 11 • 6.

SPERM CELLS

EGG CELLS		1/2 **B**	1/2 **b**
	1/2 **B**	Individual 1 Alleles: ______ Eye Color: ______	Individual 2 Alleles: ______ Eye Color: ______
	1/2 **b**	Individual 3 Alleles: ______ Eye Color: ______	Individual 4 Alleles: ______ Eye Color: ______

		SPERM CELLS	
		1/2 **B**	1/2 **b**
EGG CELLS	1/2 **B**	Individual 1 Alleles: 1/4 **BB** Eye Color: Brown	Individual 2 Alleles: 1/4 **Bb** Eye Color: Brown
	1/2 **b**	Individual 3 Alleles: 1/4 **Bb** Eye Color: Brown	Individual 4 Alleles: 1/4 **bb** Eye Color: Blue

Figure 11 • 7.

type of individual it represents will be formed by the union of a **B** egg and a **B** sperm. Since half of the eggs are **B** and half of the sperms are **B**, this combination will occur in one-half of one-half, or one-fourth, of the cases. Note that by multiplying ½ **B** × ½ **B** you get ¼ **BB.** The other boxes can be filled in the same way. Remember that **bb** results in blue eyes and both **Bb** and **BB** in brown eyes. Thus, of the possible combinations:

¼ are **BB.** They will have brown eyes.

²⁄₄ (or ½) are **Bb** (¼ **Bb** + ¼ **Bb**). They also will have brown eyes.

¼ are **bb.** They will have blue eyes.

Since the **BB** and **Bb** individuals are indistinguishable on the basis of eye color, we can also express the results as follows:

¾ will have brown eyes.

¼ will have blue eyes.

The **B** and **b** alleles in human beings are nearly always inherited as described. Sometimes, however, there are complications: there are other genes that influence the color of the eyes. Some of these modify the expression of the **B** and **b** alleles. Thus it is possible for parents who seem to have pure blue eyes to have children with brown eyes. In Investigation 11.1 you saw how variable eye color is. It is impossible to say that all eyes are either

blue or brown. The following questions, however, assume that inheritance is as simple as described in the preceding discussion.

1. What combinations of alleles are possible in individuals with blue eyes? With brown eyes?
2. Assume that in the **Bb** × **Bb** cross just described, the parents had only one child. What would be the color of its eyes?
3. Assume that the parents in Question 2 had four children, three with brown eyes. What would be the eye color of the fourth child?
4. What will be the eye color of the children of parents one of whom has blue eyes and the other brown eyes (**Bb**)?
5. How is it possible to tell whether a brown-eyed individual is **BB** or **Bb?**
6. Did the two **Bb**-type combinations shown in the genetic checkerboard inherit their alleles in exactly the same way?

INVESTIGATION 11.3: Chance and Gamete Formation—Flipping One Coin

In the example of the inheritance of eye color, the outcome depended upon chance. If the parent was **Bb**, it was a matter of chance whether a particular egg or sperm had a **B** or a **b** allele. Also it was a matter of chance which sperm and which egg united.

You can learn a good deal about chance and probability by practicing this investigation at home or at school.

MATERIALS

One coin

PROCEDURE

Flip a coin 40 times. Record how many times it turns up heads and how many times it turns up tails.

ANALYSIS

1. What fraction (¼, ⅓, or ½) of the total flips turned up heads?
2. Predict how many heads will turn up out of 100 flips. Out of 1000 flips.
3. What is the chance that a **Bb** parent will produce a **b** gamete? A **B** gamete?
4. Of 100 gametes produced by a **Bb** parent, how many should, on the average, contain **b?**

INVESTIGATION 11.4: Boy or Girl?

This investigation is designed to show how chance, in gamete formation as in coin flipping, determines the outcome.

Girls and boys are born in approximately equal numbers. If parents expect to have a baby, what is the chance that the child will be a girl? Have you ever wondered how the sex of a child is inherited?

MATERIALS

Chips (2 red, 2 blue)
Glass-marking pencils

PROCEDURES

A. You have already observed something about how genes are inherited. On the basis of what you have learned, try to make a genetic model that would produce a genetic ratio of 1 female to 1 male.

Discuss your model with others in your class. How many different models have been found? Can you reach any general conclusions?

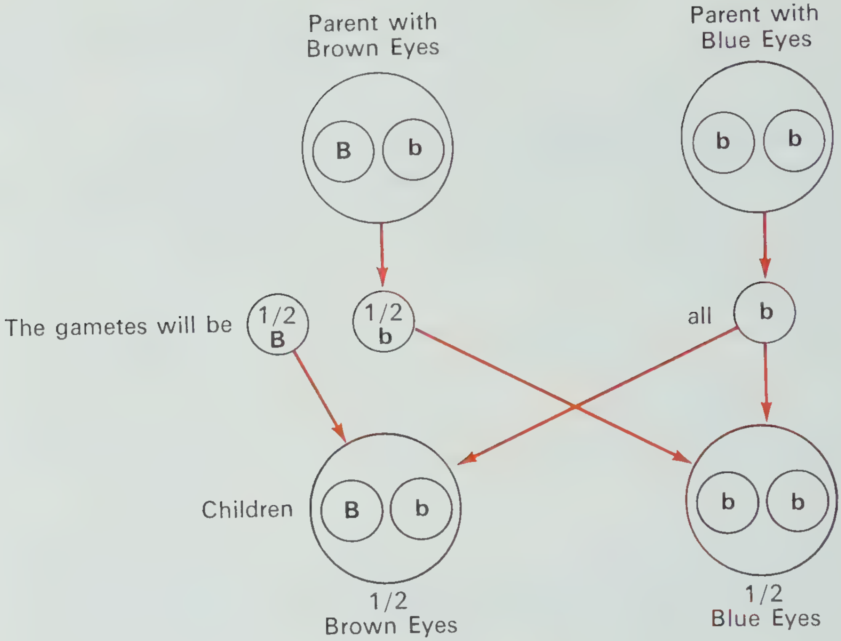
Do not read ahead until you have finished this discussion.

You may have remembered a genetic cross that produces a 1 to 1 ratio. For example, if a brown-eyed person (**Bb**) marries a blue-eyed person (**bb**), half of their children should have brown eyes and half should have blue eyes (Figure 11 • 8). The important point here is that one parent is producing two sorts of gametes, and the other parent only one.

A mechanism of the same kind determines whether a child is male or female. It has to do with whole chromosomes, however, rather than just the alleles. (Not only is this true for human beings, but the same or a similar mechanism applies to most other animals.)

If you were able to look at the 23 pairs of chromosomes of a human *female*, you would not be able to distinguish between the chromosomes of any one pair. Each member of a pair would *look*

Figure 11 • 8.



just like its mate. (You could, however, observe differences between one pair of chromosomes and another.)

If you could look at the chromosome pairs in a human *male*, however, you would find a very important difference between the two chromosomes that make up Pair No. 23. One of the chromosomes of this pair is almost twice as long as its mate. Geneticists have found that every normal human *male* has one long and one short chromosome in Pair 23. Every normal human *female* has two long chromosomes in Pair 23.

Geneticists have named the longer chromosome in Pair 23 of both male and female humans the X chromosome. The shorter one is called the Y chromosome. In other words, normal females have two X chromosomes; normal males have one X and one Y.

PROCEDURES (*continued*)

B. Take two red chips and label each X. These represent the female, with her two X chromosomes. Take two blue chips. Label one X and the other Y. These represent the male, with his X and Y chromosomes. When a mature egg is formed in

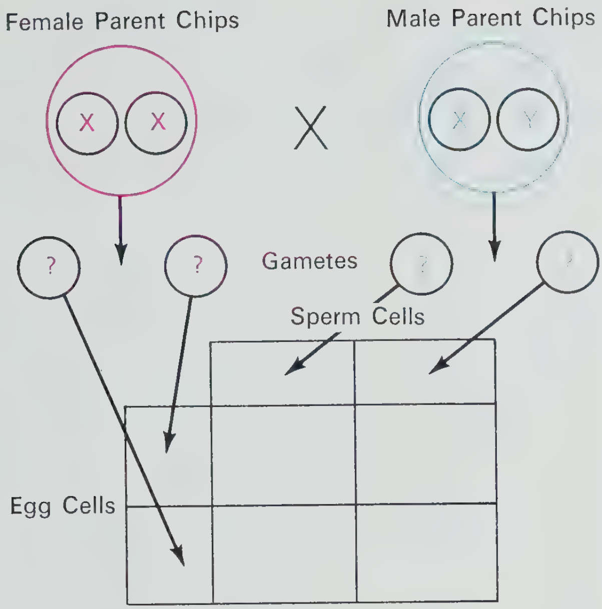


Figure 11 • 9. How to carry out Procedure B.

the female, it has only one X chromosome (either one of the female's two). When a sperm is formed in the male, it can have either the X or the Y chromosome, but not both.

Move the chips to show fertilization of eggs by sperms.

ANALYSIS

1. What is the ratio of males to females in offspring?
2. Which parent determines whether the offspring will be male or female?
3. There have been cases in history of a king divorcing a queen because she had daughters only. How well do you think such a king would do on a genetics test?
4. From which parent does a son inherit his Y chromosome? His X chromosome?
5. From which does a daughter inherit her X chromosomes?
6. If a male had a certain allele on his X chromosome, could it be inherited by his sons? By his grandsons?
7. Can you construct a genetic model to show how inherited characteristics could "skip a generation"?

Some Genetic Principles

Geneticists have studied inheritance in many kinds of plants and animals. They have discovered something surprising. In nearly all cases, inheritance follows rules of the sort illustrated by the brown-eye and the blue-eye alleles. The main rules are:

1. Every cell has two alleles of every kind of gene. The alleles may be identical, or one may be different from the other.
2. When the mature gametes (egg cells and sperm cells) are produced, each will have one and only one allele of *every* kind of gene that the parent has.
3. If an individual has two different kinds of alleles (for one of his genes) in his body cells, half of his gametes will have one allele (for that gene) and the other half will have the other allele.
4. It is a matter of chance which egg cell will be joined by which sperm cell.
5. When an individual has two different alleles of a gene, one is usually completely dominant and the other recessive. If an individual's cells contain one dominant and one recessive allele for a particular gene, the person will have the same appearance as if both of the alleles were dominant.

Some Examples of Inheritance

Here are some examples of other alleles that are inherited in the same manner as blue eyes and brown eyes:

Organism	*Dominant Allele*	*Recessive Allele*
Humans	non-blond hair	blond hair
	normal pigment	albino
	pattern baldness (males)	normal hair
	normal eyes	glaucoma

	normal sight	night blindness
	incisor teeth	no incisor teeth
	free earlobes (inside edges of earlobes not attached to cheek)	attached earlobes (inside edges of earlobes completely attached to cheek)
Horses	black coat color	chestnut coat color
Gray squirrels	gray coat color	albino
Guinea pigs	curly hair	straight hair
	black hair	white hair
Fruit flies	red eye color	white eye color
	normal wings	vestigial wings
Corn plants	tall plants	dwarf plants
	purple seeds	white seeds
	starchy seeds	sweet seeds
Pea plants	round seeds	wrinkled seeds
	yellow seeds	green seeds
	green pods	yellow pods

Although many features of an organism are results of genes that are inherited in a simple manner, some (weight, height, and shape of face, for example) are not. Many different genes affect these features. In addition, some of these features are influenced by the environment. For example, the height and weight of individuals have a hereditary basis, but their actual height and weight may be influenced by their diet. Their growth will be impaired if their diet is inadequate, or they will be overweight if they eat too much.

It was probably very surprising to geneticists to discover that inheritance followed the same general rules in organisms that looked as different from one another as corn plants, guinea pigs, fruit flies, and human beings. Their discoveries indicate that all living creatures are alike in a very fundamental way: their inheritance. Of course, groups of them are alike in many other ways, too—the ways they live, obtain their food, breathe, reproduce, and so on.

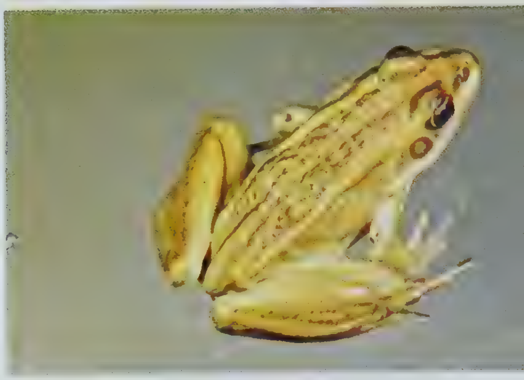
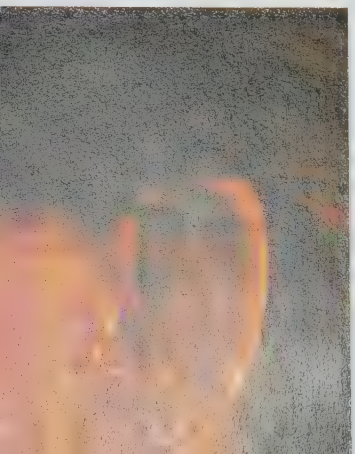


Figure 11 • 10. Some examples of traits thought to result from the inheritance of different alleles of single genes. The unspotted frog at the right has a dominant allele that prevents formation of spots. For help in answering the questions on these pages, refer to the information on pages 286–287.

Shown below are the attached earlobes of a man (*above*) and the free earlobes of his wife (*below*). If the woman has a recessive allele, what kinds of earlobes could their offspring have?



If these two guinea pigs were crossed, what color combinations could the offspring have?

Which fruit fly has a dominant allele?

Which girl could have a parent with two dominant alleles for hair color?

INVESTIGATION 11.5: Chance and Gamete Formation— Flipping Two Coins

You have collected data that show how chance works. When a coin is flipped, it can land heads or tails. Each possibility has an *equal chance* of happening. Does flipping a coin once affect the way it will land on a second flip? The answer is no. We say that the two flips are *independent* of each other. The chances are *always* ½, no matter what happened on the previous flip.

What are the chances that *two* coins flipped at the same time will both turn up heads? The answer to this question relates to the chances of different kinds of alleles ending up in the same gamete.

MATERIALS

Unlike coins, 2 (penny and nickel)

PROCEDURES

A. Assume that you are working with coins that represent alleles of traits for hair length and coat color in guinea pigs. Black color (**B**) is dominant over brown color (**b**). Short hair (**S**) is dominant over long hair (**s**).

B. Assign coat-color traits to the penny. Let heads represent the black-color allele, tails the brown-color allele.

C. Assign hair-length traits to the nickel. Let heads represent the short-hair allele, tails the long-hair allele.

D. Shake the two coins thoroughly in your hands and drop them on your table or desk. Let this represent the chance formation of either male or female gametes containing alleles for both hair length and coat color. For example, suppose both coins turn up heads. This would represent a gamete having alleles for black color and short hair (**BS**).

E. Repeat Procedure D for a total of 40 times and record your results in a chart similar to Figure 11 • 11.

Combinations	*Times*
Both heads (black, short hair)	
Both tails (brown, long hair)	
p-tails N-heads (brown, short hair)	
P-heads n-tails (black, long hair)	
TOTAL	40

Figure 11 • 11.

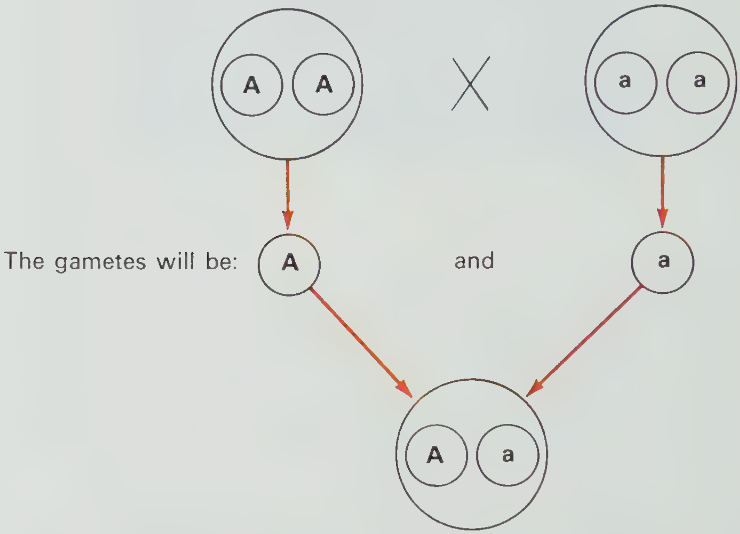
ANALYSIS

1. How many different kinds of gametes (male or female) can be represented by flipping two different coins? Remember that each coin represents two alleles and that each pair of alleles is present on two different pairs of chromosomes in the individual—the penny represents one pair of chromosomes, the nickel another.
2. About what fraction (½, ¼, ⅓) of the flips were both heads?
3. What fraction were N-heads and p-tails?
4. What fraction were n-tails and P-heads?
5. What fraction were both tails?
6. What fraction of the gametes should contain both dominant alleles? Both recessive alleles?

Two Pairs of Alleles

We have already learned how one pair of alleles is inherited. Since the rules are nearly always the same, we can make a general model. We will let **A** stand for any dominant allele of a gene and **a** for the recessive allele of the same gene. If we cross one individual that is **AA** with one that is **aa**, our model will be:

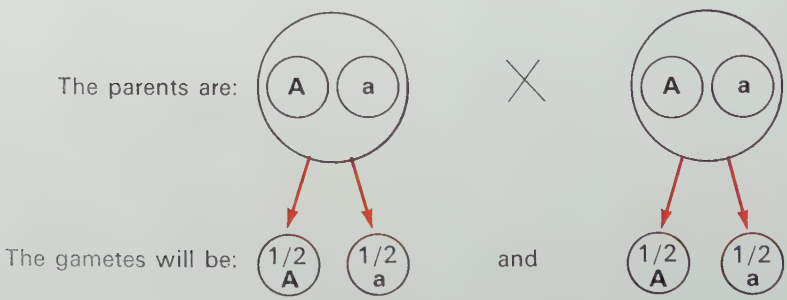
Figure 11 • 12.



These gametes will combine to produce the first-generation offspring.

All of the first-generation offspring will be alike (**Aa**) and have the appearance determined by the **A** allele. If we now cross two **Aa** individuals:

Figure 11 • 13.



The gametes will combine by chance, thus:

	1/2 **A**	1/2 **a**
1/2 **A**	1/4 **AA**	1/4 **Aa**
1/2 **a**	1/4 **Aa**	1/4 **aa**

Figure 11 • 14.

In this second generation the **AA** and **Aa** individuals all look like each other but are different from the **aa** individuals. Therefore, the ratio of the individuals in the second generation who show the dominant characteristic to those who show the recessive will be ¾ to ¼, or 3:1.

But what pattern appears if we study the inheritance of *two* pairs of alleles?

We will study two genes in corn, each with two alleles. *Purple* and *white* are alleles of a gene that influences the color of the grains (kernels). Purple is dominant to white. Let **P** stand for purple and **p** for white.

Smooth and *wrinkled* are alleles that also influence the appearance of the grains. The smooth grains are round and plump in appearance because of the accumulation of starch. The wrinkled grains are shrunken because of the accumulation of sugar. Smooth is dominant to wrinkled. **S** stands for smooth and **s** for wrinkled.

The alleles for purple and white color are carried by one pair of chromosomes. The alleles for smooth and wrinkled are carried by a different pair of chromosomes. Since the different pairs of alleles are carried by separate pairs of chromosomes, they are inherited independently of each other. These two pairs of alleles will illustrate the most common type of inheritance observed when two genes are on different chromosomes.

Assume that one plant is *pure* (has like alleles for the genes in question) for purple and for smooth. We will represent it as

PPSS. The other plant is white and wrinkled. It will be **ppss.** The cross will be **PPSS** × **ppss.**

What kinds of gametes will be formed by these plants? You should be able to decide—if you remember that every gamete will have one, but only one, of each kind of chromosome. Expressed in another way, every gamete will have one, but only one, allele of each gene. Therefore all gametes of the **PPSS** plant will be **PS,** and gametes of the **ppss** plant will be **ps.**

All the individuals (corn grains) produced from the union of these gametes will be **PpSs.** These grains will be purple and smooth in appearance.

INVESTIGATION 11.6: A Cross Involving Two Pairs of Alleles

What will be the results of a cross between two **PpSs** plants?

Divide the class into three different kinds of teams. No. 1 teams should each have two students. No. 2 teams should each have three students. No. 3 teams should each have two students.

MATERIALS

Red chips, 40
White chips, 40
Glass-marking pencil
Bowls, 4 (or 600-ml beakers)
} . . . . For No. 2 Teams

Genetic corn, 1 ear . . . . For No. 3 Teams

PROCEDURES FOR NO. 1 TEAMS

The two plants being observed are **Pp** for color and **Ss** for the smoothness trait. Each normal gamete produced by the plants will contain one allele for color and one allele for smoothness. There are four different combinations of these two pairs of alleles that can end up in gametes—**PS, Ps, pS,** and **ps.** (There are four possible combinations of *any* two pairs.) Since these combinations are usually produced in nearly equal numbers, ¼ of the gametes should contain the combination **PS,** ¼ **Ps,** ¼ **pS,** and ¼ **ps.** The two parents being crossed are genetically alike, so they

will produce the same kind of gametes. The offspring can be determined if you fill in the squares in a genetic checkerboard.

A. Copy Figure 11 • 15 in your notebook and fill in the squares.
B. Of the 16 possibilities (the number of squares in the checkerboard), how many of the grains should be:
   (1) purple and smooth?
   (2) purple and wrinkled?
   (3) white and smooth?
   (4) white and wrinkled?

Gametes from Parent 1

Gametes from Parent 2	PS	Ps	pS	ps
PS				
Ps				
pS				
ps				

Figure 11 • 15.

PROCEDURES FOR NO. 2 TEAMS

A. Use red chips to represent the purple- and white-colored alleles and white chips to represent the alleles for smooth and wrinkled.
B. Label 20 of the red chips **P** and 20 **p**. Put 10 **P** and 10 **p** chips in one bowl, the rest in a second bowl. Each bowl represents the color alleles for one parent.
C. Label 20 of the white chips **S** and 20 **s**. Place 10 **S** and 10 **s** chips in a third bowl, the other **S** and **s** chips in a fourth bowl. Each of these bowls represents the smooth and wrinkled alleles for one parent.
D. One student on the team should take one bowl of red chips and one bowl of white chips. Another student should do the same.
E. Shake each bowl. Without looking, each of the two students should take one chip from each of his bowls. These chips represent the alleles that each gamete will receive by *chance*.

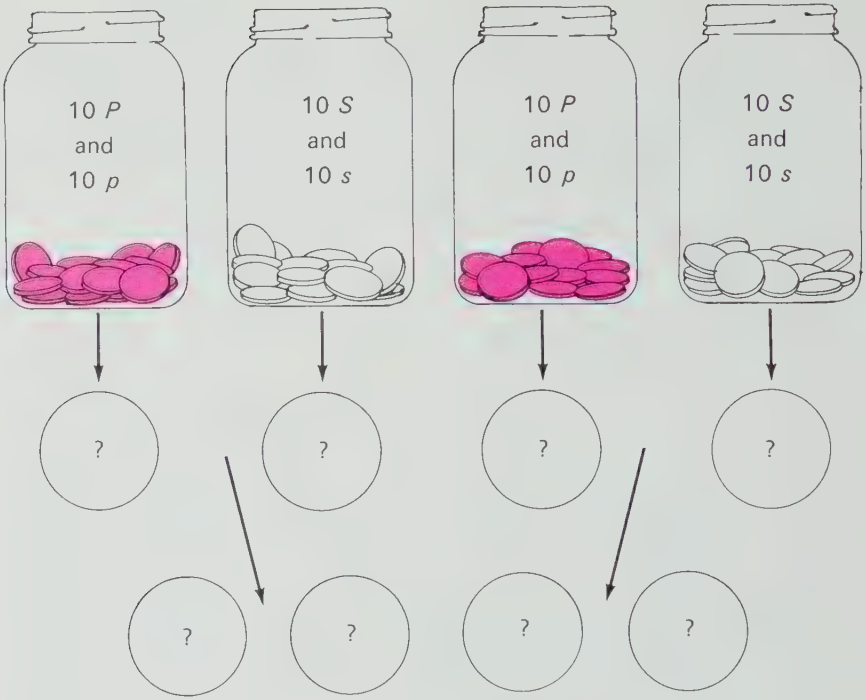


Figure 11 • 16. Diagram illustrating Procedures B–E.

The two chips from each student should then be lined up to represent the alleles in the offspring.

F. The third member of the team should keep track of the number of times that each possible combination occurs. Copy Figure 11 • 17 and record your results.

Figure 11 • 17.

Combination	*Times This Combination Occurs*	*Appearance*
PP SS		
PP Ss		
PP ss		
Pp SS		
Pp Ss		
Pp ss		
pp SS		
pp Ss		
pp ss		

G. *After each combination has been recorded, the chips should be returned to the containers from which they were taken.* (Each combination represents a possible offspring.)

H. Procedures E and F should be repeated until about 100 combinations have been recorded.

I. You should determine what the appearance of the offspring will be for each combination of alleles. Summarize these data in a chart like Figure 11 • 18.

Appearance	*Number of Grains*	*Percentage of Grains*
Purple, smooth		
Purple, wrinkled		
White, smooth		
White, wrinkled		
Total		100%

Figure 11 • 18.

PROCEDURES FOR NO. 3 TEAMS

A. You will be given an ear of corn produced from a **PpSs** × **PpSs** cross. Examine the ear carefully and note that each grain on it is either purple or white and *also* either smooth (plump and round) or wrinkled. You are to determine how many grains of each sort resulted from the cross.

B. Notice that one of the grains at the end of a row has been painted black. This is a marker. One student should begin with this row and determine the characteristics of each grain on the ear.

C. The other student should record the data in a chart like Figure 11 • 19.

Type of Grain	*Number of Times Occurred*
Purple, smooth	
Purple, wrinkled	
White, smooth	
White, wrinkled	
Total	

Figure 11 • 19.

Be very careful with the ear of corn. Do not remove any grains from the ear. Do not mark the grains with a pencil or pen when you are counting them. When you have counted all the grains on the ear, summarize your data as follows:

(1) % purple and smooth:
(2) % purple and wrinkled:
(3) % white and smooth:
(4) % white and wrinkled:

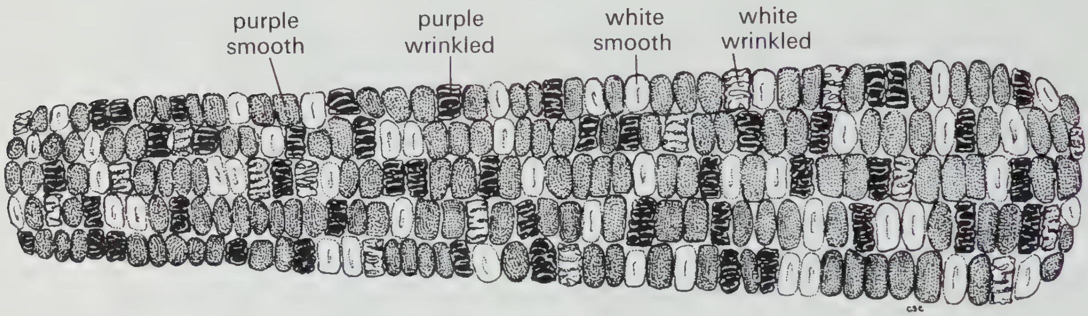


Figure 11 • 20. Drawing of an ear of corn produced from a **PpSs** X **PpSs** cross.

All the similar teams should compare their results. Be prepared to report the average results of your study.

No. 1 Teams: Describe the techniques used and the results obtained.
No. 2 Teams: Describe the techniques used and the results obtained.
No. 3 Teams: Describe the techniques used and the results obtained.

ANALYSIS

1. Compare the results of the three different kinds of teams.
2. Describe how the techniques of the three differed.
3. In this cross, each pair of alleles, considered alone, gives a ratio of ¾ to ¼ in the second generation. Can you figure out what the ratios would be when *both* pairs of alleles are considered together?
4. Can you figure out what the ratios would be for *three* pairs?

How Genes Change

Imagine that you are given a wild organism (animal or plant) and asked to study its genetics. If it were like most wild organisms, all individuals in its species would look very much alike. Possibly it would be a beetle, with glossy black wing covers, six legs, and so on. How would you go about studying its genetics?

You might first cross two adults. Probably all the young would look exactly like the adults. You certainly could not conclude much from that—apart from the basic biological principle that offspring tend to resemble their parents.

Genetics is concerned with the *inheritance of differences.* If all of the organisms being crossed are alike, one learns nothing about their genetics. For example, suppose that the beetle does have a gene—call it **A**—that influences the color of the wing. If all individuals are **AA**, crossing would give offspring that can only be **AA**.

A geneticist would know nothing of the inheritance of such a gene unless it somehow changed—say to a recessive allele, **a**, which could result in the wings being yellow. Then **AA** × **aa** would give **Aa** offspring—all with black wings. If two of the **Aa** beetles were crossed, their offspring would have a ratio of 3 with black wings to 1 with yellow wings.

We would then know for the first time that this gene for wing color existed in two allelic forms, **A** and **a**.

The change of an allele from one form to another, for example, from **A** to **a**, is known as a *mutation.* If **a** were to change back to **A**, this also would be a mutation.

Mutations have been found in all organisms that geneticists have studied. But they occur very rarely. For most genes the rate of mutation is probably less than once in 100,000 generations.

How do mutations happen? In the process of cell division, one cell becomes two. During this process each chromosome forms another one. Normally the new chromosome is exactly like the original one. A mutation may be thought of as a mistake—one of the genes in the new chromosome is not copied exactly. It is not known what causes mutations to occur in nature. It is possible, however, to change genes by experimental means. For ex-

Figure 11 • 21. Gene mutations are among the factors responsible for many different expressions of one trait. How would you describe the variation in the flowers? Combs are fleshy crests on the heads of fowl. How would you describe the variation in the chicken combs shown?

ample, X rays cause genes to mutate. X rays can also cause chromosomes to break or otherwise be damaged. Mustard gas and some other chemicals can cause genes to mutate, too. And nuclear explosions and wastes from nuclear reactors (if not properly disposed of) can produce radiations that can cause mutations.

Most mutations are harmful. Sometimes, though rarely, mutations are beneficial. Thus it has been possible in some cases to improve domesticated varieties of animals and plants by exposing them to X rays. The desirable alleles can then be selected.

X rays and other agents that cause mutations do so in a haphazard manner. That is, they cannot be made to cause mutation of a specific gene. When a mutation does occur, it seems to be largely a matter of chance which gene will mutate.

Single comb

Strawberry comb

Sweet William

Comb absent

Rose comb

Extending Your Knowledge

Genetic knowledge is often used to produce better varieties of plants and animals. Let us suppose that in corn there is a gene with two alleles that determines the number of grains: **AA** individuals produce many grains; **aa** individuals produce fewer grains. Let us also suppose that there is another gene with two alleles that helps to protect the corn against disease: **BB** individuals are resistant to disease, and **bb** individuals are susceptible. If a geneticist had two strains of corn, one with the **AA** and **bb** alleles and the other with the **aa** and **BB** alleles, how might a superior variety of corn that had many grains and was resistant to disease be produced?

A

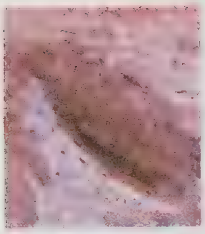
B

C

Figure 11 • 22. Brahman cattle (*A*) live well on dry range but produce inferior meat. Shorthorn cattle (*B*) produce good meat but live poorly on dry range. Santa Gertrudis cattle (*C*) do well on dry range *and* produce good meat. How do you think ranchers developed the Santa Gertrudis breed?

SECTION TWELVE

Change Through Time



When people dig into the earth to make foundations for buildings, to obtain minerals, or to construct tunnels under rivers, they may find strange things. If they dig in Rome or Athens, they often come across pieces of pottery, statues, and tools. These were made and used by the people who lived in these cities in ancient times. Recently, workmen digging for the new subway in Mexico City came across remains of ancient temples and objects thought to be the treasures of the last Aztec emperor. These objects had been hidden to prevent their falling into the hands of Cortés and his Spanish soldiers.

Thus evidences of human life in the past are buried in the earth. We can learn a great deal about the life of ancient people from the remains of the tools they used and the buildings they constructed. Sometimes we also find remains of the food they ate and the clothing they wore.

Figure 12 • 1. Recent excavation of Aztec buildings in Mexico.

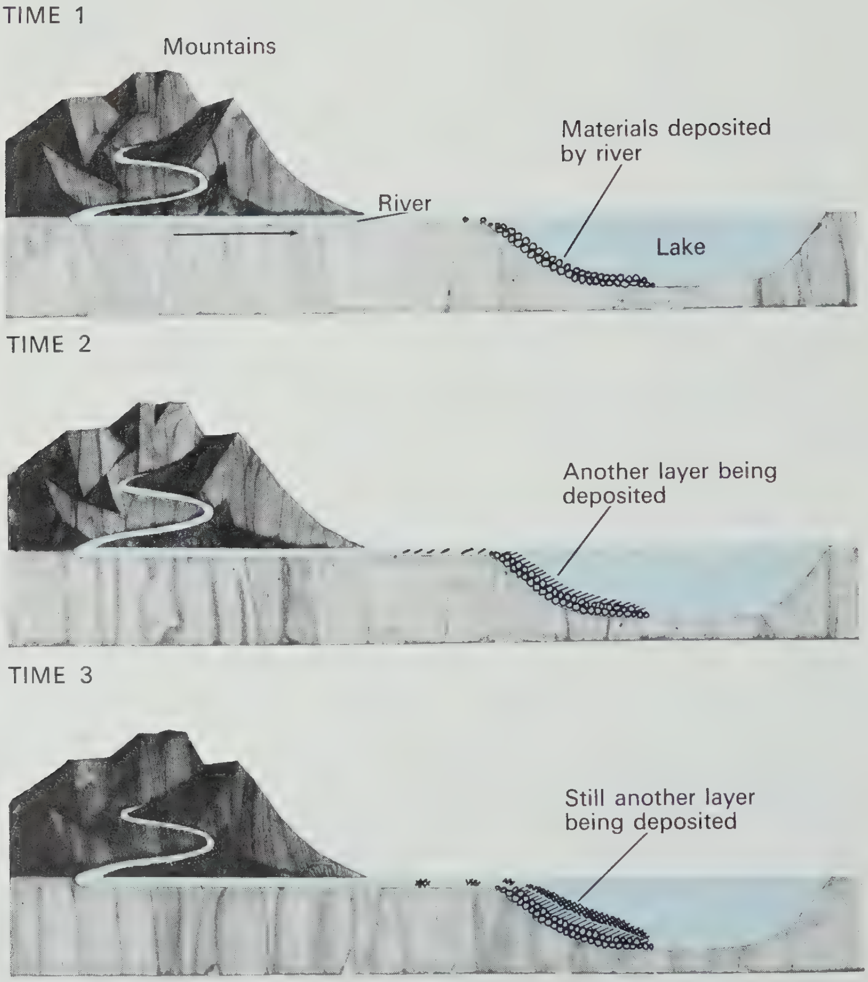
It is even possible to tell something about how long ago the people lived. You can probably guess how this can be done by thinking about the problem. Let us assume that there is a hill near a river and, on one side of the hill, a deep gully with steep walls. Long ago the area was rich in game animals and there were many fish in the river. Nearby there were deposits of clay and flint, and there were also many trees. We will assume that humans came to this site thousands of years ago. It was so rich in food and other resources that they settled on the hill. Different tribes came and fought over the land, but we will assume that it was occupied by different groups of people for thousands of years. We will also assume that the inhabitants threw most of their trash into the gully next to their hill. Thus, over the years, there was a slow accumulation in the gully of animal bones, broken pots, ashes, and broken tools. This junk pile could help us understand something about how these ancient people lived. Could you tell anything about the age of the items from their *positions* in the junk pile?

The earth also has its junk piles. For example, a river may wash material downstream and deposit it in a lake or in the ocean (Figure 12 • 2). The material coming down in later years will spread over that previously deposited at the river's mouth. Each layer represents a particular time.

If an animal dies and is washed down the river, its decaying body may be buried in the mud at the river's mouth. Probably only the bones finally remain. These slowly change as minerals in the water penetrate them and convert them into a stonelike material. We speak of this change as *fossilization* and of the altered remains of the bones as *fossils.* (However, not all fossils are the remains of bones. Footprints of giant animals, like dinosaurs, that lived during prehistoric times are also considered fossils. The cover photograph for this section shows such a fossil footprint. Compare the size of the dime with the size of the footprint.)

Over the ages, the mud at the bottom of the lake may slowly change to stone. The lake may disappear. There will then be layers of rocks, which will contain fossils.

Figure 12 • 2.



If we dig into one of these natural junkyards, we may find evidence of animals and plants that lived in the past, just as we find evidence of our existence and past activities when we search through ancient garbage heaps. From such diggings, scientists have been able to piece together a picture of what life may have been like many millions of years ago.

A Field Trip Through Time

At this point, suppose you take an imaginary field trip, years into the past. Not just a few years into the past, or a few thousand—but millions. You should take along collecting equipment—traps, butterfly nets, insect-killing jars, something to put plant specimens in. And certainly you will want to take along some field guides so that you can identify the plants and animals you encounter.

An interesting place to go might be northeastern Utah, because this is wilderness country—with beautiful sandstone canyons and piñon-juniper woods, lizards, coyotes, and golden eagles. The region is semiarid, so don't worry about taking boots or a raincoat; however, it may be chilly if you make the field trip in winter.

But this field trip into the past would turn out to be considerably different from one made today. The piñon-juniper woodland would be missing. In its place would be a tropical rain forest. The climate would be anything but semiarid. Warm rain would drench you and the mud would be up to your ankles. The bird, mammal, and plant guides would do no good, because none of the animals or plants you would see on this trip into the past are described in them. And the traps that you brought along wouldn't be quite large enough to use to capture the 20-meter dinosaurs you would see.

The main impression you would get from such a field trip is that there have been some tremendous changes in northeastern Utah over the past hundred million years. The jungle swamp has turned into a dry sandstone canyon. And the dinosaurs that disappeared have not just wandered off to be replaced by lizards. Here we are dealing with tremendous changes—changes not only in the climate but also in the kinds of animals and plants existing in Utah.

Part of the Dinosaur National Monument is located at the site of your field trip. This land (Figure 12 • 3) now contains many interesting kinds of animals and plants. There is nothing peculiar about them. They occur in many other western states. But in the Monument area there used to be some strange creatures that no

Figure 12 • 3A. Like the plants, the animals of this large area in Colorado and Utah have characteristics that allow them to survive in the dry climate.

Figure 12 • 3B. Two typical organisms of Dinosaur National Monument, a sagebrush plant (*left*) and a sage hen (*right*).

longer exist. By digging into the rocks, one may discover some exciting things. For example, the remains of many kinds of dinosaurs, both large and small, have been discovered there (Figure 12 • 4). Scientists can tell from the kind of fossils they find that this region was warm and swampy when the dinosaurs were alive. (If you were told that fossils of reindeer were found, you would probably conclude that the region was very cold when these ani-

mals were alive. In a similar way, fossils of palm trees would suggest a warmer climate.)

Not only was the ancient climate of the Dinosaur National Monument very different from what it is today, but so were the animals and plants. There is no animal or plant living anywhere on the earth today that is the same as those whose fossils have been found in the Dinosaur National Monument.

How would you account for these ancient animals? What happened to them? Is there any relation between them and the modern animals of the area?

In an attempt to answer questions like these, scientists have carried out many kinds of studies. They have dug in the rocks for fossils of all the animals and plants that they can find. They have tried to learn what these ancient organisms were like and to compare them with those living today. It is usually possible to determine whether the organisms lived on land or in the sea. And quite often it is possible to determine something about the climate they lived in.

Studies of this sort, plus many others, have convinced the scientists who asked these questions that animals and plants have *evolved*. That is, the kinds of animals and plants that are alive today are descendants of different kinds of animals and plants that lived in the past. The working hypothesis of these scientists is that originally there were a very few kinds of primitive life. Slowly, over many millions of years, these first organisms evolved into many other kinds of animals and plants. Finally, they evolved into the kinds that are alive today. Some of the evidence that has convinced scientists that evolution has occurred is presented on the following pages.

The theory of evolution has been very important in biology. It offers an explanation for the origins of the kinds of life that we observe around us. For more than a century, scientists have been studying this problem. They have concluded that all of their discoveries can be explained by the theory of evolution and that none of the evidence contradicts the theory. Nevertheless, many details about life in the past and about how evolution occurs are still not known.

Discovering the Ancient Biosphere

Figure 12 • 4. *Below, left:* The area of Dinosaur National Monument might have looked like this 160,000,000 years ago. *Below, right:* A fossil insect preserved in amber.

Fossils must be measured and cataloged.

Above: Worker exposing a fossil. Such work must be done with great care.

Below: Brontosaurus, a resident of North America many millions of years ago.

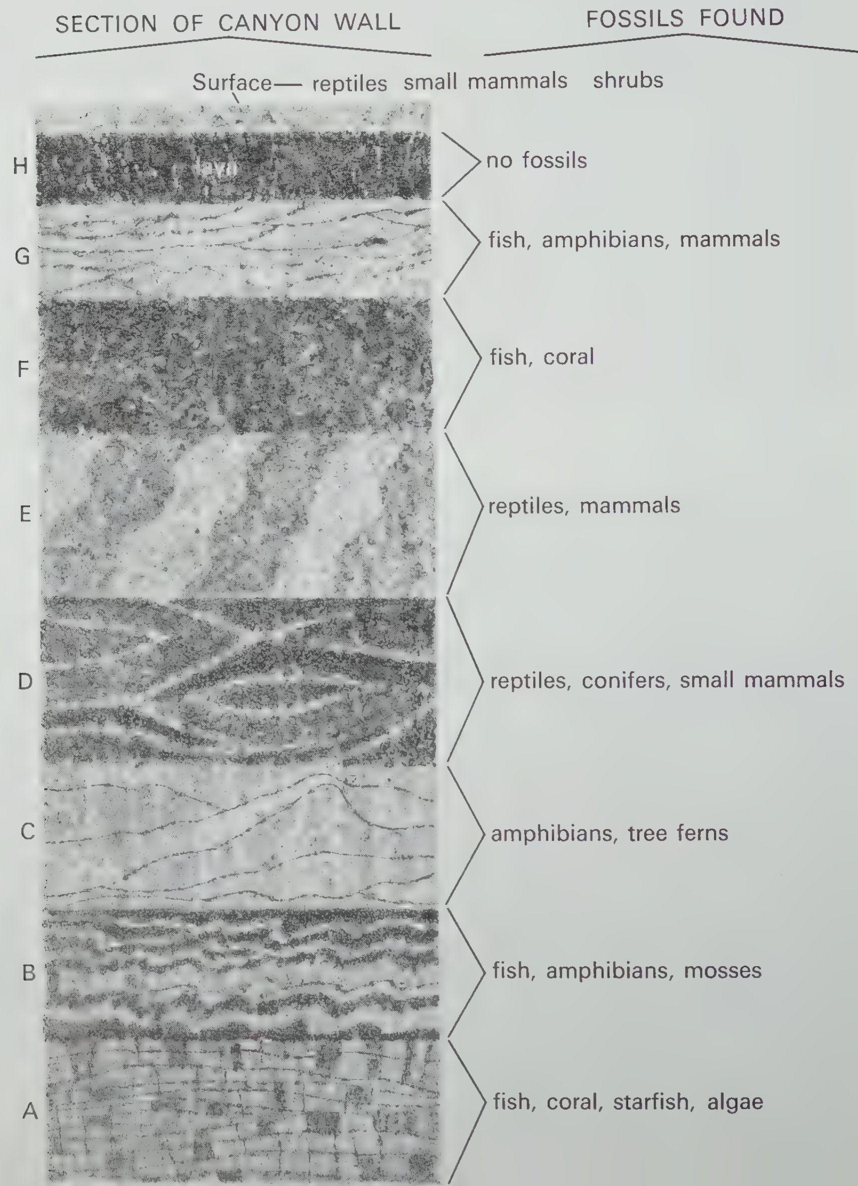
INVESTIGATION 12.1: Interpreting Evidence from the Past

What information about evolution can you gain by inspecting a fossil bed? What can be discovered about the organisms and the environment of the past?

PROCEDURES

A. Carefully study Figure 12 • 5. It shows many different layers of rock that were exposed by the cutting action of a river as it

Figure 12 • 5.



formed a deep canyon. Scientists believe that the many layers were formed when eroded soils were deposited there long ago, as shown in Figure 12 • 2. As the soil was deposited, the bodies of plants and animals of that time may have been caught in the mud. Most of the organisms simply decayed, but some were preserved as fossils.

ANALYSIS

1. Which layer do you think is oldest?
2. Describe how you think the environment may have changed as these layers were formed.
3. Explain the appearance of fish and coral in Layer F. Why do you suppose no mammal fossils were found there?
4. Why do you think there are no fossils in Layer H?
5. Does the absence of fossils in a layer necessarily mean that no plants or animals lived in the area when that layer was formed?
6. Which group do you think is older—fish or mammals?

Figure 12 • 6. The Green River canyon in Dinosaur National Monument was cut by the action of flowing water. Many layers of rock containing a fossil record of life in this region have been exposed.

Figure 12 • 7. Skeletons and some artists' reconstructions of what early forms of the horse may have looked like. The pictures show some details of front feet. Notice how the feet have changed through time.

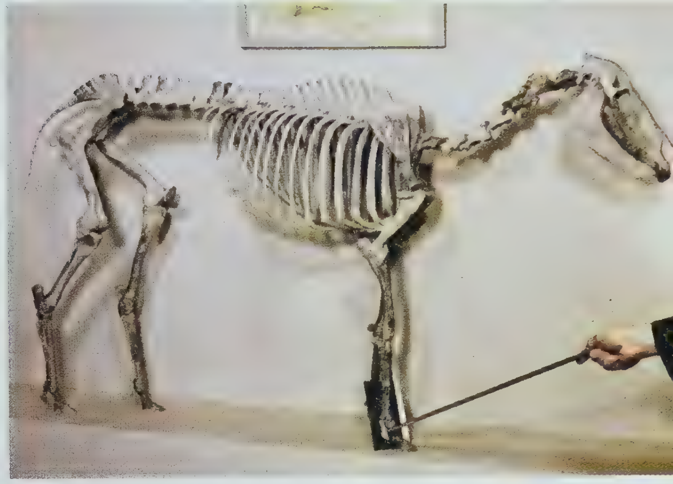
Evolution of the Horse

The best evidence for evolution comes from a series of fossils that show a trend from one sort of animal to another. Some of the most interesting evidence available concerns the horse. Scientists have discovered hundreds of thousands of fossils of early horses and now know at least the broad outlines of horse evolution. The story began about 70,000,000 years ago; some of the highlights are shown in Figure 12 • 7.

Eohippus lived about 50,000,000 years ago. It was about the size of a small dog, and four of its five toes on the front foot reached the ground.

Mesohippus lived about 35,000,000 years ago. This animal was about the size of a large dog. Each front foot had three toes that reached the ground.

Merychippus lived about 20,000,000 years ago. Its size was between that of a large dog and a Shetland pony. The outside toes did not reach the ground.



Pliohippus lived about 15,000,000 years ago. This mammal was larger than a Shetland pony, almost as large as a modern horse. Very little remained of the two outside toes.

This modern wild horse is smaller than some of its artificially selected descendants, such as Percherons or Clydesdales. Figure 12 • 9 shows some of the variety that has been developed in modern horses.

INVESTIGATION 12.2: A Model for Evolution

What additional evidence do scientists have to show that evolution has occurred? One source of evidence is the different kinds of animals and plants that have been domesticated. You have probably seen various breeds of horses, such as slender racehorses and heavy workhorses.

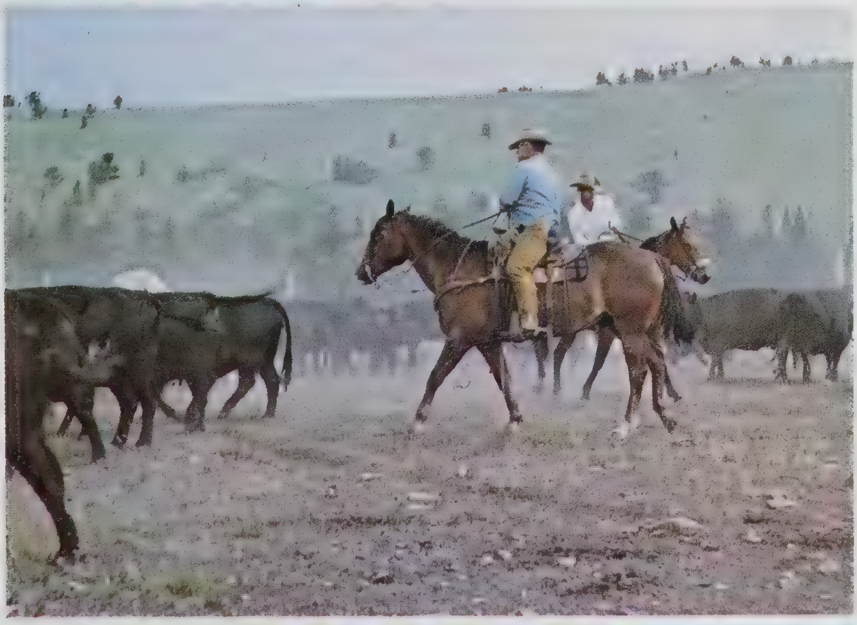
It is believed that primitive people first tamed the horse between 4000 and 5000 years ago. For centuries before that, they killed wild horses for food. The horses that were tamed belonged to a single species that was found in many parts of Europe and Asia (Figure 12 • 8).

Figure 12 • 8. This species of wild horse, still alive in parts of central Asia and in some zoos, was the ancestor of the horses pictured at the right.

All the varieties of domesticated horses were developed from this one species of wild horse. Some of the modern breeds are shown in Figure 12 • 9. Some breeds have been selected for work, such as pulling a plow or wagon. Some have been selected for transporting humans—when they tend cattle, for instance—or for use in pleasure riding and racing. Still others have been selected for use in circuses.

Figure 12 • 9.
Some modern horses.

Thoroughbred



Quarter horse

Below, left: Arabian

Below, right: Draft horses

Before reading any further, develop a hypothesis to suggest how these domesticated varieties could have been produced. It will be important for you to recall what you have learned about genetics. Discuss your hypothesis with other students.

MATERIALS

Box labeled *gene pool*, with 80 to 120 cards, half labeled *heavy* and half labeled *slender*

PROCEDURES

A. Let us assume that the ancestral wild-horse population had many different genes that controlled body form. Assume that in this population there were equal numbers of *heavy* and *slender* genes. The interaction of these genes produced the medium build of the wild horse.

B. The class should divide into 2 kinds of teams of 4 members each: *racehorse teams* and *workhorse teams*. One *racehorse team* and one *workhorse team* can share a "gene pool" box.

C. The *racehorse teams* should begin with 6 cards labeled *heavy* and 6 cards labeled *slender* (taken from the gene-pool box). These cards will represent the wild ancestors of the *heavy* and *slender* horses. *Racehorse teams* will try to replace the 6 cards labeled *heavy* with 6 labeled *slender* so that all 12 of their cards will be labeled *slender*. They can do this by first shaking the gene-pool box and then drawing (*with eyes closed*) one card at a time from it. Each time a card is drawn, one card should be put back into the gene pool. Keep track of the number of drawings it took to get 12 cards labeled *slender*.

D. The *workhorse teams* should begin with 6 cards labeled *heavy* and 6 labeled *slender*. These cards will represent the wild ancestors of the horses. *Workhorse teams* will try to get 12 cards all labeled *heavy*. They can do this by drawing (*with eyes closed*) one card at a time from the gene pool. Each time a card is drawn, one should be put back into the gene-pool box. Keep track of the number of drawings required.

ANALYSIS

1. How many generations (drawings) did it take to obtain a racehorse or a workhorse?
2. How might you obtain a racehorse or a workhorse by breeding individuals such as the wild horse that is shown in Figure 12 • 8?

How Evolution Occurs in Nature

Charles Darwin, a famous biologist of the 1800's, made many observations of living things. These observations made him wonder if populations of animals and plants change over long periods of time. Eventually he came to the conclusion that they do change.

The first point in Darwin's theory was that members of a species tend to produce large numbers of offspring. He also observed that there are many different kinds of offspring.

You know that genetic variations exist within any species. As a result of sexual reproduction, new combinations of existing genes may be formed in offspring. Additionally, new genes may be formed as a result of mutation. (Darwin did not know about genes or mutations, but their discovery supports his theory.)

Some variations may be very valuable in helping animals or plants to survive. Individuals possessing these variations tend to survive and produce more of their own kind. Other individuals lacking the variations are often unsuccessful and do not live to reproduce. Different environments favor different variations. Thus, in a desert, animals and plants that could live on small amounts of water would have a better chance of surviving than those needing much water.

In the process of competing for survival, those individuals with beneficial adaptations succeed. They have been selected by nature. Thus, they have the opportunity to produce more of their own kind. Darwin and others called this "survival of the fittest through natural selection."

Most scientists are of the opinion that natural selection is the main way by which organisms change with time.

ANALYSIS

How would you compare the evolution of the breeds of horses with evolution as it occurs in nature?

INVESTIGATION 12.3: Random Selection in a Large Population

You can understand some of the factors that are responsible for evolution by studying models.

MATERIALS

Gene cards from a shuffled deck, half of them marked *light* and half *dark*

Gene card marked either *eaten by birds* or *escaped from birds*

PROCEDURES

A. Obtain two gene cards from your teacher. These cards represent genes for color in an insect. *Dark* is dominant, and *light* is recessive. Determine the color of your insect.

B. Obtain an *eaten by birds* card or an *escaped from birds* card from your teacher.

C. During Summer 1, only those insects with *escape* cards live to reproduce and donate genes to the next generation. Those insects that receive *eaten* cards do not reproduce, and their genes are removed from the population.

D. Your teacher will record on the board the number of dark and light insects that escaped. The number of dark and light alleles that remained after Summer 1 will also be recorded.

E. Repeating the above procedures, record numbers of dark and light insects and alleles remaining after four or five summers.

ANALYSIS

1. What determines the selection of insects to be eaten?
2. What happened to the ratio of dark to light insects between Summer 1 and Summer 4?
3. What might happen to the color composition of the population during ten summers? Twenty-five?
4. What happened to the ratio of dark to light alleles in the population during the four summers?
5. What might happen to the color composition of a population of 10,000 insects during several similar summers?

INVESTIGATION 12.4: Nonrandom Selection in a Large Population

During the previous investigation, you obtained data to show what happens to an insect population if birds eat the insects at random. In this investigation, you will see what happens to a similar insect population when birds select the insects on the basis of color. That is, birds tend to eat more insects of one color than of another. Assume that the insects in this population spend most of the day resting on the trunks of trees. The tree trunks are very dark because of an accumulation of soot from nearby factories.

MATERIALS

Cards from Investigation 12.3

PROCEDURES

A. Obtain two gene cards from your teacher. Determine your insect's color. Record on the board the color composition of the population to which it belongs.
B. Obtain an *eaten* or *escaped* card from your teacher.
C. During Summer 1, all insects with an *escaped* card live to reproduce, no matter what color they are. Dark insects with an *eaten* card also survive to reproduce. Only light insects with an *eaten* card do *not* survive to reproduce. Their genes are removed from the population.
D. Record the number and color of the surviving insects. Also record the number of alleles of each color that survive.
E. Repeat Procedures A–D for four or five summers.

ANALYSIS

1. Why might birds eat mostly light insects in this area?
2. Is light color a helpful variation for insects in this environment? Would it be helpful in a woods where the tree trunks were light?
3. What happened to the ratio between the number of dark insects and the number of light insects during four summers?
4. What happened to the ratio of dark-to-light alleles in the pop-

ulation during four summers?

5. What would happen to the original insect population if it were placed for ten summers in a woods with light tree trunks?

Natural Selection in Tadpoles

Not many years ago a biologist looked into a small pond with a gray, muddy bottom and counted about 500 toad tadpoles. Most were dark, but a few were white (albinos). He counted 75 albinos. The next morning he found tracks of a raccoon at the edge of the pool—he counted only 49 white tadpoles that day. The morning after that there were only 27 albinos; the third morning there were only 9. The fourth morning he found 7 white tadpoles. On that day he carefully estimated the number of dark tadpoles to be about 400. Every morning there were fresh raccoon tracks.

FOR CLASS DISCUSSION

1. If the raccoon was wholly responsible for the disappearance of tadpoles, how many of the dark ones had it eaten? How many of the light ones had it eaten?
2. Why do you suppose the raccoon caught more white tadpoles than dark ones?
3. What do you think the composition of the tadpole population was the following year?
4. If this pond had a white, sandy bottom, which color tadpole would the raccoon probably catch more frequently?

Combining Ideas to Make a Theory

The ideas that you have been exposed to in this section and in Section Eleven can be put together to make up one of the most important theories in science, the theory of evolution. Here is a list to remind you of some of these ideas:

1. The characteristics of organisms are determined or greatly influenced by their genes.
2. Genes are inherited in an exact way.
3. Genes are usually very stable. That is, a gene stays the same unless there is a mutation that changes one of its alleles to another form.
4. The various genes with their different alleles can be combined in many different ways, and different sorts of individuals will result. Some may be large, others small. Some may eat one kind of food, others different kinds. Some may tolerate cold better than others. Some may prefer a dry climate, others moisture.
5. Many species will flourish only in a specific environment. Different sorts of organisms will flourish in different environments. A population of organisms that flourish in one environment may be exterminated if the environment changes rapidly.

What can we do with this information?

Let us think of an imaginary population, Species A. Let us also make up an imaginary place for it to live in. The place could be the edge of a continent: a broad area of coastal lowlands and a range of mountains. Let us assume that Species A lives in Zone 1. In Zone 1 the climate is warm and moist. Here Species A flourishes. Zone 2 is also in the lowlands, but it is too dry for Species A to live in successfully. Zone 3 is in the mountains, where the environment is too harsh for Species A. Zone 4 is in the lowlands, but its climate is too cool for Species A. The situation at Time 1 is shown in Figure 12 · 10A.

Let us now assume that the lowlands of Zone 1 begin to sink slowly, possibly just a few centimeters every century. (Geologists

have discovered that in some parts of the earth the coast is sinking slowly; elsewhere it is rising). The sea will someday begin to cover Zone 1. The area where Species A can live will gradually become smaller and smaller. Thus, the number of individuals originally present will not be able to find food or places to live. In time Species A may become extinct—when the sea entirely covers Zone 1. But it will not necessarily become extinct—there is a saving possibility.

Using the information we previously obtained, let us try to imagine what is occurring where Zones 1 and 2 meet. Zone 2 has an environment that is warm and dry—an environment in which Species A cannot flourish. In fact, we can even assume that in the part of Zone 1 nearest to Zone 2, life will not be too successful for our species.

But Species A is a large population. There are many individuals, with many different sorts of alleles. When the individuals mate, these alleles are distributed in different combinations among the offspring. A tremendous number of such combinations is possible. Some of the combinations may lead to individuals that can live a little better in a warm-dry climate than the rest of Species A. They will be better *adapted* to warm-dry conditions than individuals without these alleles. That is, they will have changed their structure, physiology, or behavior in ways that improve their chances for surviving and leaving offspring in their new environment. As a result, as the generations pass, those alleles that allow individuals in Species A to live fairly well in warm-dry environments will become relatively abundant.

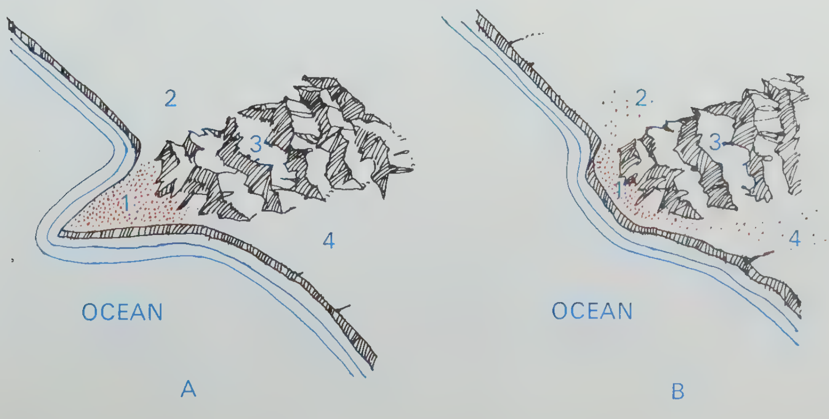


Figure 12 • 10.
A. Map at Time 1.
B. Map at Time 2.
The dots indicate the density of Species A organisms. Zone 1 is moist, Zone 2 is warm and dry, Zone 3 is mountainous, and Zone 4 is cool and moist.

By Time 2, many generations later, we would expect to find some individuals with the combination of alleles that enables them to live in a warm-dry climate. These can then push their way into Zone 2. And the same thing could be happening at the junction between Zones 1 and 4. That is, some of the individuals of Species A may have alleles allowing them to live in a cool-moist environment. We have summarized the situation existing at Time 2 in Figure 12 • 10B.

Let us now continue to Time 3, when the sea will have entirely covered Zone 1. Then all of the individuals in Species A either will be dead or will be in Zones 2 and 4. Remember that the individuals in Zone 2 are not exactly like those in Zone 1. They have alleles that better adapt them to the warm-dry conditions of Zone 2. Since they are different, we should recognize this by calling them A-2. Similarly, those individuals in Zone 4 with alleles adapting them to cool-moist conditions can be called A-4.

At Time 3 the population will have split into two areas: the mountains have prevented their coming together. The alleles in the A-2 population will continue to combine in many ways, and some of the ways may better adapt the individuals to Zone 2. In addition, new mutations may result in alleles better adapted to the warm-dry environment.

We can imagine this process continuing in Zones 2 and 4 for thousands of years. Gradually A-2 and A-4 will become increasingly adapted to their environments. And in so doing, A-2 and A-4 will become less like each other. In fact, they may become so different that they can be recognized as two separate species. Or we can say that the ancestral species has evolved into two new species.

Evolution means that organisms change with time: species slowly become better adapted to their environment. Under some situations, a species population may slowly change into something so different from the ancestral population that we can say a new species has evolved. One example is seen in Figure 12 • 7.

Biologists and geologists have made many observations leading them to believe that the sorts of things we have discussed about horses and tadpoles happen commonly in nature. Artificial

selection by people and natural selection in nature result in changes in populations. These changes generally occur very slowly.

ANALYSIS

1. The ancestor of all domesticated dogs is thought to have been a wild animal resembling a wolf. You have seen many different breeds of dogs. How do you think they were formed?
2. In the example of the evolution of Species A into A-2 and A-4, what was the effect of the land's sinking?
3. What was the environmental effect of the mountain range in Zone 3?
4. Draw a map showing land, water, and species distribution at Time 3.

Extending Your Knowledge—A Lifetime Activity

Once you are familiar with the theory of evolution, the world should never look the same to you again. When you see layers of rock in a cliff (Figure 12 • 6), think of their origins. They were laid down as mud or sand long ago and slowly changed to stone. Possibly they contain the fossil remains of animals and plants that lived in the past. When you see the many varieties of food products in the supermarket, think of their origins. All the foods began as wild species, and people have greatly influenced their evolutionary history. People have selected those that have best suited their purposes: varieties that give more milk, more meat, better wool, more eggs, more grains, sweeter fruit, and so on. Similarly, when you look at the many kinds of wild animals and plants, think of their origins. They, too, have been through a long period of selection, but nature has done the selecting, not people. Some are adapted for life in water, others for life on land, and a few for life in the air. Some are large, others are small. Some can live only in deserts, others only in warm jungles. But all are the result of nature's selecting those most able to survive and leave offspring in the part of the earth that is their home.

We Can't Run Away Any Longer

Until recently our species did not have much influence on the biosphere. When our ancestors were hunters, they killed the animals and gathered the plants needed for food and clothing. They used stone for tools and clay for pots. These activities exterminated no animal or plant species and polluted few streams. Their campfires did not seriously pollute the air. Such small amounts of natural resources were used that even if mankind had not existed, it would have made no noticeable difference.

When human beings became more numerous and more civilized, they did begin to make a difference. This was especially true in Europe, where most of the forests were destroyed long ago. In addition, domesticated animals overgrazed grassland, which then became unproductive wasteland. So many children were born that the land could not support the ever-increasing population. Wastes began to pollute the streams and the air. All of this meant that the local environment could not tolerate human activities—natural resources were being destroyed faster than nature could replace them.

But there was always a solution—move. Many European people found new homes in Africa, North America, South America, and Australia. For

several centuries these new lands could supply their needs and cope with their wastes. Nature seemed so big, and for a while human demands on the biosphere were not great.

Things are very different now. There are no new continents to be discovered. Nearly all the land that can be used to grow our food is being used. We can't run away any longer to a place where there is an abundance of fertile land, clean air, plenty of natural resources, and unpolluted streams. For the first time in history, we must face this choice: Either we learn to live *with* nature, or we cannot live at all. We can no longer live by destroying nature and then moving on.

Your parents now face this choice, and in the years to come *you* will have to face it. More water is needed in homes and industry—yet we are polluting what water we have. We enjoy the convenience of the automobile—but its exhausts are making the air in many of our cities harmful to health. We need more food—yet some of our agricultural practices actually destroy the ability of the land to produce.

The environmental crisis is the result of several hundred years of living as well as we can at the moment with no thought of tomorrow. The problems resulting from such thoughtless behavior cannot be cured overnight. Though the situation is serious, it is probably not hopeless. In nearly every instance we have the knowledge and ability to solve environmental and social problems. More and more, industries and governments are making efforts to cooperate in improving environmental conditions. Lead is being removed from gasoline. Automobile manufacturers are spending large sums of money to design engines that will consume less gasoline and produce fewer pollutants. We may see new types of cars in production within a few years. Cleaner, faster systems of public transportation in and between cities are being designed and built. There is widespread concern about the extinction of wildlife species. Chemicals such as phosphates in detergents, long-lasting pesticides, compounds containing mercury, and many other polluting substances are being banned. New methods of reclaiming water from sewage are being designed. Many factories are being equipped with filters and with other smoke-control devices. The use of "clean-burning" fuels is increasing. New methods and better locations for disposal of solid wastes are being sought. The two most important questions of all this: Even though we have the way to solve these problems, have we the will? Can the individuals in our society cooperate to help solve these problems?

You might wonder: What can one person do to keep the world livable? Perhaps the first thing to do is change the question to: What must *I* do? There is quite a lot. All of us, both individuals and groups, must gradually change our lives so that we begin to live in balance with the biosphere. We must not use renewable resources faster than they are renewed by nature. We must think of nonrenewable resources as a heritage to be cherished, not squandered. We must insist that industries not dump their wastes into streams and lakes—killing the fish and making the water unsuitable for drinking. We must insist that means be taken to reduce air pollution—from industry and from automobiles. We must save enough of the undisturbed landscape to ensure the survival of wild animals and plants—and to provide ourselves with places to observe and enjoy nature.

These and other large, long-range tasks will require action and support from all parts of our society—government, industry, but most of all the general public. You can help by indicating your concern not only in the way you live but also in letters to your local newspapers, business leaders, representatives, senators, mayors, or governors. And, before long, you will be able to vote for those politicians who show they care about the environment and are anxious to protect it.

There are also things you can do that will make a difference immediately. Most people are thoughtful, but some are not. You may see litter in the streets, in parks, or in parts of your school yard. If you and your classmates decided not to litter, and also decided that every day each of you would pick up one piece of paper or an empty bottle and put it in a trash basket, you would soon have a much more pleasant environment.

But more than anything else, you must think. You now know a great deal about the biosphere. You know that it is in delicate balance and must be treated gently. It is up to each of us to see that what we, our communities, and our countries do will not interfere with that balance. We must protect the biosphere—it is the only one we have.

Appendix A

Working With the Microscope

A microscope is among the scientist's most valuable tools. A fascinating world of tiny plants and animals can be seen when it is used correctly. Like many tools, microscopes are delicate and expensive. *Remember, your microscope is probably the most expensive piece of equipment you will use this year.* Use it and care for it according to instructions.

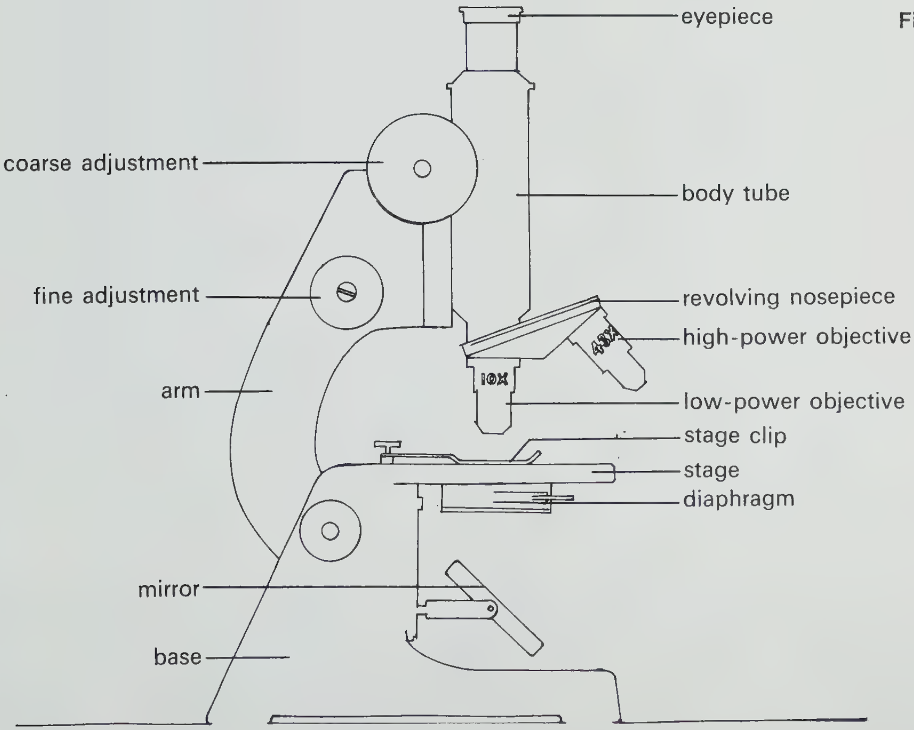


Figure A • 1.

Before doing work with the microscope, find all the parts labeled in Figure A • 1 and be able to name them. Most microscopes have about the same kinds of parts, but they may not look alike. Even though your microscope appears to be different from the one illustrated, your teacher can give you some help in finding

all the parts labeled. As you learn how to use the microscope, you will discover the purposes of the parts.

When you carry the microscope to and from your desk, be sure to use both hands. One hand should be under the base. The other hand should hold the arm. Always hold the microscope upright (as in Figure A • 1). This will keep the eyepiece from slipping out of the body tube. Put the microscope down on your desk gently, with the arm toward you. If you store the microscope in a cabinet, be sure that the top of the body tube does not hit the cabinet when you put it in or take it out.

An object to be examined under a microscope is usually placed on a small piece of glass known as a slide. For your first study, cut a short word containing the letter *e* out of a newspaper. Next take a clean slide and put two drops of water in the center. Shake the water off, but do not dry the slide. Now place the piece of newspaper in the wet area and press it down gently until it is wet and sticks to the slide. Next put two drops of water over the paper. Take a clean cover glass and hold it at an angle of about 45°, as shown in Figure A • 2. One edge of the cover glass should be in the drop of water on the slide. Carefully lower the cover glass to cover the piece of paper. It may help you lower the cover glass if you support the upper edge with a toothpick or pencil. There should be no air bubbles under the cover glass. If there are, you can usually remove them by *gently* pressing on the cover glass with a pencil.

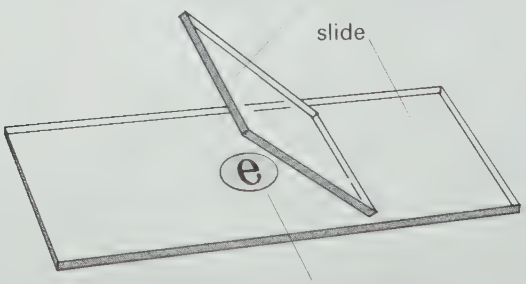


Figure A • 2.

The slide you have made is called a *wet mount*, because the material you are to view has been put in water. Most of the slides you will make will be of this type.

The next steps will explain how to use the microscope:

1. Put the slide on the *stage* of the microscope so that the letter *e* is centered over the opening in the stage. The *stage clips* can be used to hold the slide in place.
2. Turn the *revolving nosepiece* until the *low-power objective* clicks into place.
3. While watching from the side, turn the *coarse adjustment* and lower the *body tube* until the low-power objective is about 2 mm from the slide. Some microscopes have an automatic stop that keeps the objective from reaching the cover glass and breaking it; but be careful, because yours may not have such a stop.
4. Move the *mirror* so that light is reflected up through the body tube and *eyepiece*. *Never use direct sunlight* as a light source, for it can damage your eyes. A desk lamp, the sky, or a microscope lamp may be used. Some microscopes have built-in light sources instead of mirrors.
5. Look through the eyepiece and carefully turn the coarse adjustment toward you, lifting the body tube, until the letter comes into view. If you don't see the letter, lower the body tube and try again, raising the tube more slowly. If you still have no results, move the slide a little. Perhaps the letter was not centered; you may be looking at a clear area.

   You should adjust the *diaphragm* so the right amount of light is reaching your eye. Too much light will cause glare; too little will keep you from seeing anything. Proper lighting of each slide you prepare will often make the difference between seeing an object or not seeing it.

   Practice keeping both eyes open. Doing this will reduce eyestrain.

   Once you can see the letter, use the *fine adjustment* to make the object on the slide as clear and sharp as possible.
6. Note the appearance of the letter *e* on the slide compared with its appearance as seen through the eyepiece. Watching the letter through the microscope, move the slide to the right. Which way does the letter seem to move? Move the slide to

the left, then up and down, and note which way the letter seems to move.

7. You can determine the magnification by multiplying the magnification of the low-power objective by the magnification of the eyepiece. The eyepiece is usually 10 X and the low-power objective is usually 10 X. The total magnification for the microscope is $10 \times 10 = 100$ times when the low-power objective is used. In other words, the letter *e* appears to be 100 times larger than when seen with the unaided eye.
8. The next step will be to rotate the nosepiece to bring the *high-power objective* into position. Before doing this, make sure the object is centered in the field of view and is in clear focus. Watch from the side to keep the high-power objective from hitting the slide. Most microscopes can be switched from low to high power without moving the coarse adjustment. When the microscope has been changed to high power, the light may have to be adjusted again. Usually more light will be needed.

   Never touch the coarse adjustment after the microscope has been changed to high power. A slight turn of the fine adjustment one way or the other should bring the letter *e* into focus.

   What is the magnification of the letter *e* when the high-power objective is used? Check the magnification of the eyepiece and the high-power objective before you try to answer this question.

Here are a few hints if you have difficulty in using the microscope properly:

1. Make sure the lenses of the microscope are clean. Your teacher will show you how to clean them. Use only the lens paper that is provided. Cloth or other types of paper may damage lenses.
2. Adjust the lighting properly by using the mirror and the diaphragm. Most beginners try to use too much light.
3. Make sure your slide is centered. The object must be directly under the lens of the objective.
4. Air bubbles are common on wet mounts and can cause confusion. If the microscope reveals something that is round and black, with a clear center, it is probably an air bubble.

5. Do not tilt the microscope. This is very important when using wet mounts.
6. If you cannot find the object using high power, start all over again with low power and work back to high power.
7. If you still have trouble, ask your teacher for assistance. It is better to ask a question than to risk damaging an expensive piece of equipment.

Appendix B

Collecting and Caring for Insects and Spiders

I. INSECTS

Collecting

Insects are probably the easiest kind of animals to find and collect. They can be found almost everywhere and at most times of the year. Summer is the best time, but insects are active from early spring into late fall. Even in winter many hibernating ones can be found. Try to collect most insects during the day. If the weather is rainy or cold, don't expect to find very many.

Some places where a collector can look for insects:

1. Many are found near or on plants. In fact, almost any part of a plant may have insects on it. Do not overlook small insects.
2. Look on, around, and under debris. Boards, dead leaves, rocks, dead animals—all might provide hiding places for insects. Most insects are harmless to people. But there are a few that can inflict painful bites or stings. Be very cautious if you are collecting in an area inhabited by poisonous reptiles.
3. Places where people or animals live can hide insects. Look in corners, cracks, and crevices. Insects that attack living things can be found around those living things. If you just sit in the shade on a warm day, the insects probably will come to you.
4. Look around lights. Put a light over a bucket of water on a

warm night. Insects will come to the light, and some will fall into the water. You might even do a little research on insects and light. What color of light attracts the largest number of insects? What different kinds of insects are attracted by various colors?

5. Water insects can be found in ponds, lakes, streams, and rivers. Look for them on the surface, under the surface, in mud, under and on rocks, and on submerged sticks.
6. Try raising your own adult insects from cocoons, larvae, or other immature forms. In this way you can watch behavior and changes that take place in growing insects.

Many insects can be captured by hand—sometimes with the aid of a pair of tweezers. A helpful aid in capturing flying and stinging insects is an insect net. Nets can be purchased from most biological-supply companies or can be made with little effort.

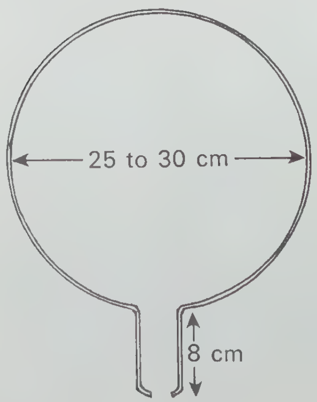
MATERIALS (for one net)

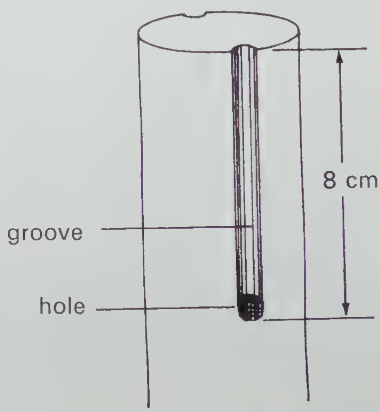
½-inch doweling, 90 cm
Wire coat hanger, 1
Mosquito netting (or any similar cloth that has a mesh weave)
Copper wire
Drill
Strip of muslin (or any other medium-weight cloth)

PROCEDURES

A. Shape the coat hanger into a rim, as in the following sketch:

Figure B • 1 (*left*).
Figure B • 2 (*right*).





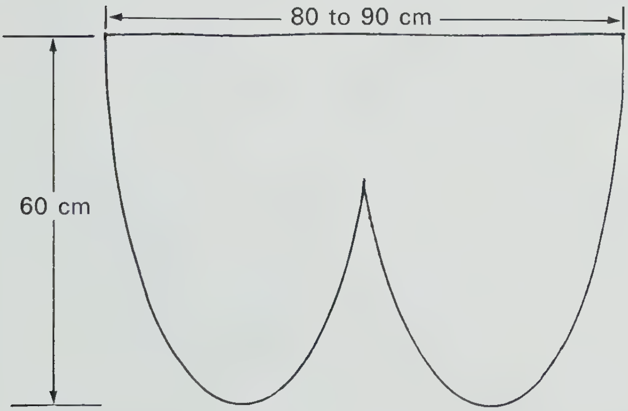
B. Cut a 3-mm-deep groove along each side of the piece of doweling. The groove may be formed with the edge of a file. Drill a hole 3 mm (⅛ inch) in diameter from the end of one groove to the end of the other. A power drill can be used for both jobs, but the drilling should be done by someone who is familiar with the equipment.

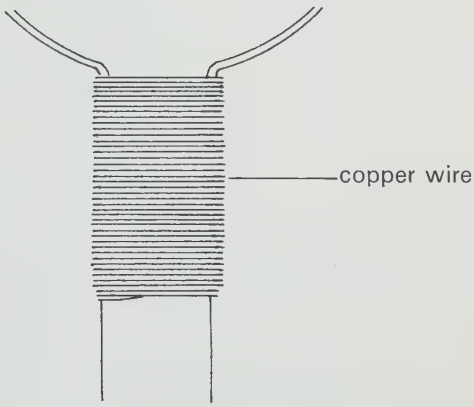
C. Cut the netting in the general shape of Figure B • 3.

D. Fold the netting in half and sew the edges to form a cone. Use muslin or some other heavy material to attach the net to the wire rim.

E. Attach the net to the doweling with the copper wire. This net should last for a long time. Keep it out of barbed wire, sharp thorns, and water.

Figure B • 3 (*left*).
Figure B • 4 (*right*).





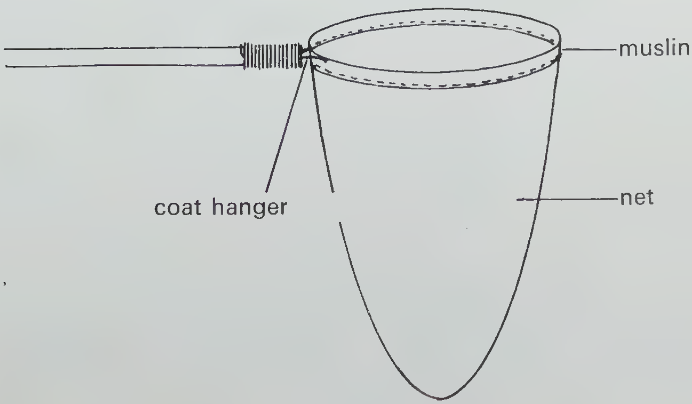


Figure B • 5.

Killing Insects

Once an insect has been captured, it must be put into a killing jar so it can be handled and prepared for study. The safest jar is one that contains ethyl acetate as the killing agent. Ethyl acetate is readily available from scientific supply companies and is somewhat safer than carbon tetrachloride. Avoid breathing ethyl acetate fumes—they are poisonous.

MATERIALS (for one killing jar)

½-pint jar (peanut butter, etc.)
Rubber bands or pieces of rubber tubing
Ethyl acetate
Absorbent cotton
Heavy cardboard, cut to fit into the jar
Jar lid
Masking or adhesive tape

PROCEDURES

A. Pack some rubber bands (or cut-up tubing) into the bottom of the jar.
B. Soak the rubber bands in ethyl acetate. After soaking, pour off the excess, if any.
C. Place absorbent cotton over the rubber bands. Then cut a piece or two of heavy cardboard that can be put over the cotton. Punch a few holes in the cardboard to allow the fumes to come up from the rubber bands.
D. It is a good idea to wrap the bottom half of the jar in masking tape or adhesive tape so the contents will not be scattered if the jar should be broken.
E. Label the jar *POISON* so other people are aware of the danger. Make sure the jar is tightly covered when not in use. Since the fumes will escape, the ethyl acetate will have to be replaced from time to time. (Caution: Ethyl acetate is flammable.)

The length of time that an insect has to remain in the jar before dying will depend upon its size and type. Large crawling insects might have to stay in the jar for an hour or more. Ethyl ace-

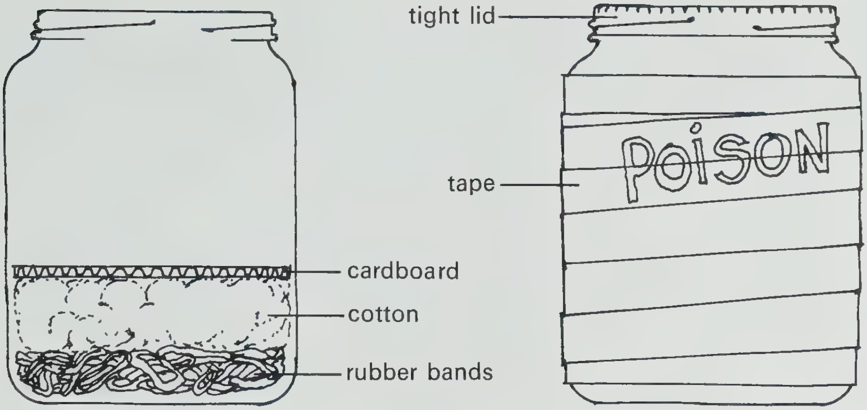


Figure B • 6.

tate will dry out insects very quickly, so it is a good idea to prepare your insects soon after taking them out of the killing jar.

Preparing Insects for Display and Study

It is not too hard to collect insects, but it is somewhat difficult to prepare them so they can be kept permanently for study, and as a source of information and enjoyment.

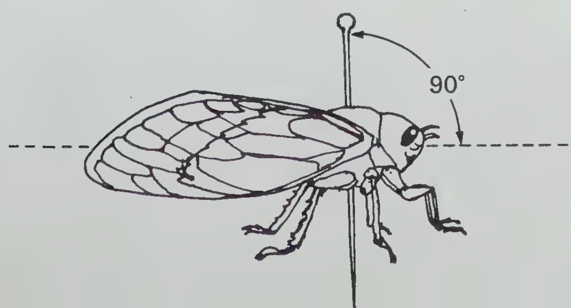
MATERIALS

Insect pins (No. 2 or No. 3. They can be obtained from biological-supply companies or any scientific-equipment store.)
Heavy cardboard
3 x 5 index cards

PROCEDURES

A. Put the insect on the cardboard, legs down. Pin the insect through the body so the body is at a 90° angle to the pin. Always place the pin a little to the right side of the insect's midline (see Figure B • 7). The point of the pin should extend about 2.5 cm below the insect's body.

Figure B • 7.



The following types of insects should be pinned through the thorax (second body segment): most stinging insects, flies, butterflies and moths, grasshoppers, crickets, and dragonflies.

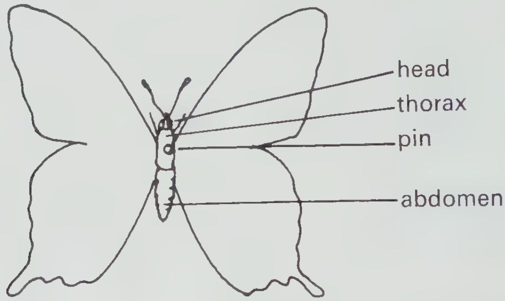


Figure B • 8.
NOTE: *The rear edge of the front wing of a properly mounted butterfly should be at a 90° angle to the body.*

A true bug or beetle can be pinned through the wings that cover the abdomen.

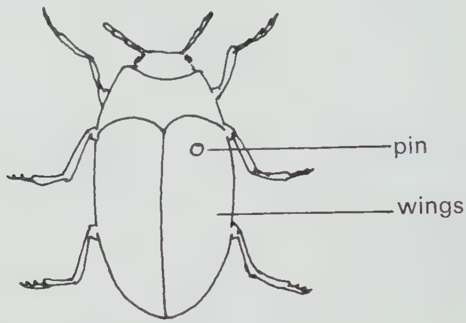


Figure B • 9.

B. Each insect that is collected should have two labels. The labels should be spaced about 1 cm apart under the insect, on the pin holding it. For each insect, cut two 0.5- by 2-cm labels from index cards (or other heavy paper). On one label write when the insect was collected, where it was collected, and the name of the collector.

C. After you have identified the insect, write the generic and specific names on a second label. If you cannot find the generic or specific name, put down the family or order name. Last, on the same label write the insect's common name. Place this label just below the first label.

April 5, 1975

Dingville, California

Joseph Dow, collector

Figure B • 10.

Genus	Papilio
Species	Papilio philenor
Family	Papilionidae
Order	Lepidoptera
Common name	Pipe-vine swallowtail butterfly

Figure B • 11.

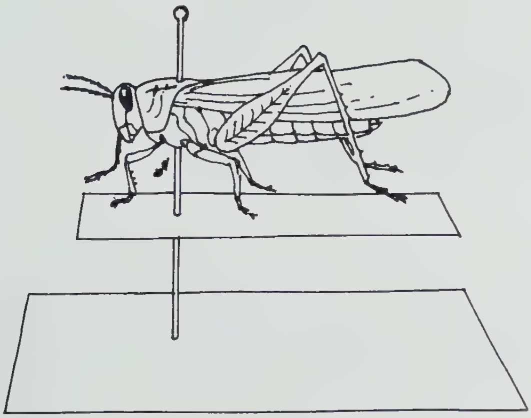


Figure B • 12.

It takes special handling to properly display some insects, such as moths and butterflies. The beautiful, colorful patterns of the wings can be shown only if they are spread. Devices for spreading the wings may be made or obtained from supply companies. The following materials are needed to make a spreader:

MATERIALS

2.5-cm pieces of softwood, 2 (If nothing else is available, use several pieces of thick cardboard.)

Cork or other soft material

Glue

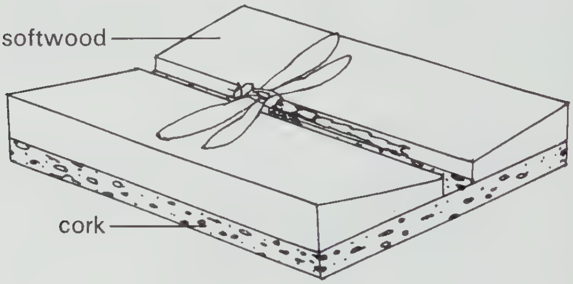
Paper

PROCEDURES

A. Glue the two pieces of wood to the cork, leaving a channel between the two pieces just large enough to contain the body of the insect.

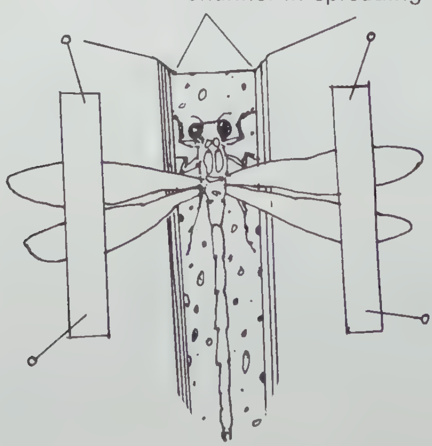
B. Push the pin through the insect's thorax and into the cork. The top of the body should be just level with the top of the channel. Remember, the insect should be 2.5 cm above the point of the pin. Be careful that the pin is not bent when it is put into the cork. Arrange the insect's legs as they would be in life, and use tweezers or pins to spread the wings.

Figure B • 13.



C. Pull the front wings slightly forward so as to almost clear the hind wings. Use strips of paper to hold the wings down in proper position. Be careful that the fuzzy material on the wings is not rubbed off. The final product might look like Figure B • 14.

Figure B • 14.



Let the specimen dry for 24 hours or longer, depending upon the size of the insect.

Sometimes an insect becomes brittle and difficult to pin. If this happens, put some moist cotton or sand in the bottom of a jar. Cover the moist material with absorbent paper, such as blotting paper, or with several folds of paper towel. Place the insect in the jar for 24 hours. This should make it soft enough to work with. Do not leave it in the jar more than 24 hours, or mold may grow and destroy the specimen. If mold does begin to grow, keep the jar and the insect to be softened in a refrigerator for as long as it takes to relax the insect.

Displaying Your Insect Collection

After insects have been pinned, you will need some type of container to keep and display them in. You could use cigar boxes. They are strong and fit neatly on a bookshelf, but they may not be deep enough or you may not be able to obtain any. Also, boxes can be homemade, or insect-display boxes can be purchased. Whatever the kind of box, make sure there is some type of soft material in the bottom so pins can be inserted. Strips of glued-down balsa wood work very well. Or the bottom of the box can be lined with cork or cardboard. To dress up the boxes, paint them with a latex paint. Moth crystals sprinkled in each of the display containers will keep out pests that might destroy the display. Renew the crystals from time to time, for they will evaporate.

Riker Mount

To display insects without pinning them, put them in a Riker mount. This method works well with most insects, but it is especially effective with moths and butterflies.

MATERIALS

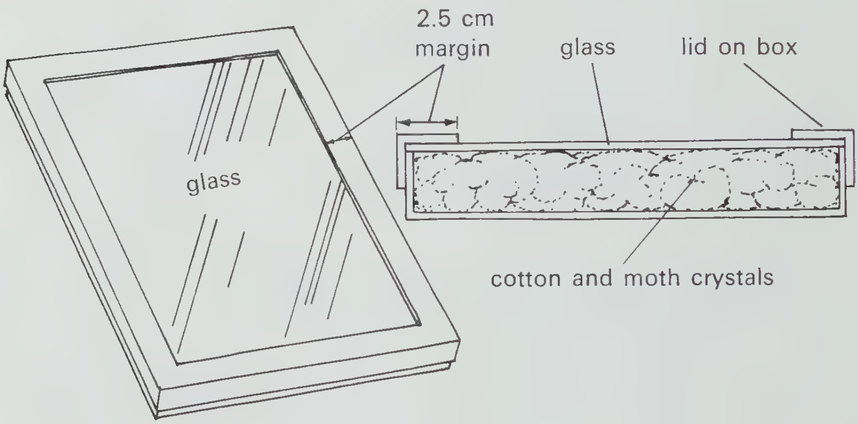
- Nylon-stocking boxes
- Glass or heavy, clear plastic
- Glue
- Roll of cotton
- Moth crystals

PROCEDURES

A. Cut out the center of the top of the box you are using for display, leaving a 2.5-cm margin. Cut a piece of glass or clear, heavy plastic to fit the top of the box.
B. Glue the glass or plastic in place. If you want to paint the box, do so before you glue on the glass or plastic.
C. Put cotton in the box and place on the cotton the specimen to be displayed. Sprinkle moth crystals in the box. Fasten the top down with straight pins in each corner or with masking tape.

The Riker mount is useful for a variety of other things besides insects. Seeds, leaves, flowers, and so forth, can also be displayed in these containers.

Figure B • 15.



II. SPIDERS

Collecting Spiders

Although you may collect spiders by yourself, it is usually best to go with a partner. Two can usually find and capture spiders more effectively than one. Quite often a good time to collect spiders is at night (because some spiders are nocturnal predators), and you will need someone to handle a flashlight. In addition to a flashlight, you will need several small jars with lids and a few 3 x 5 file cards or pieces of paper.

In collecting a web weaver, use one hand to place the open end of a jar near the underside of the spider. With the other hand,

carefully place the jar lid above the spider and then *very quickly* fasten the lid.

NOTE: *There is enough air in the jar to keep the spider alive for a day or two. You need not puncture the lid.*

You can collect a running or jumping spider by placing the open end of a jar over the spider. It may then climb into the jar, allowing you time to close it with the lid. If the spider does not climb into the jar, try sliding a 3 x 5 file card under the spider. You can then pick up the jar, invert it, and with a quick downward movement of the jar, shake the spider to the bottom. Then remove the card and cover the jar with a lid.

You can collect some spiders by sweeping an insect-catching net back and forth through dry grass and around brush. You may think of other methods to try. With a little experience, you will be able to collect dozens of spiders.

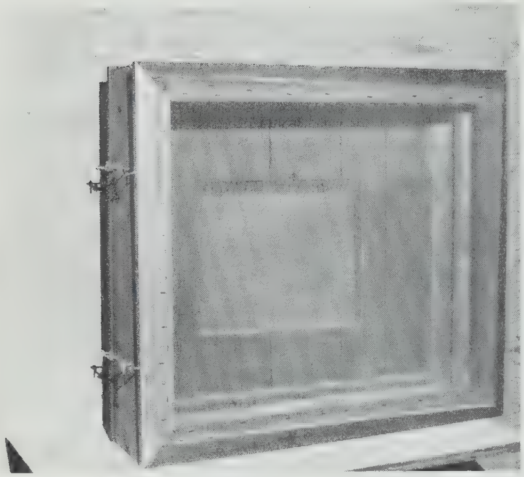
You should avoid black-widow and brown-recluse spiders. They are poisonous and they will not exhibit any behavior that cannot be observed in other spiders. See Figures 8 • 18 and 8 • 19, page 192, for examples of these two spiders.

Caring for Spiders

Once you have collected one or more spiders, they should be transferred to a suitable "spider house." This can be a Mason jar, a drinking glass, an aquarium, or a specially built cage.

If you use jars or drinking glasses, prepare a cotton stopper to insert into them. Select a large enough batch of cotton to fit tightly into the mouth of the jar or glass. Wrap cheesecloth around the cotton and tie it firmly. Transfer the spider from the collecting jar to its new home. You can do this easily by placing the two jars together and shaking the spider downward into the laboratory jar. Quickly stopper the jar with the cotton plug. Air will enter the jar through the cotton—the cheesecloth will prevent the spider from becoming entangled in the cotton.

Often you can study spider behavior in more detail if you build a cage that is more like a spider's natural habitat. Three types of cages are shown in Figures B • 16, B • 17, and B • 18.



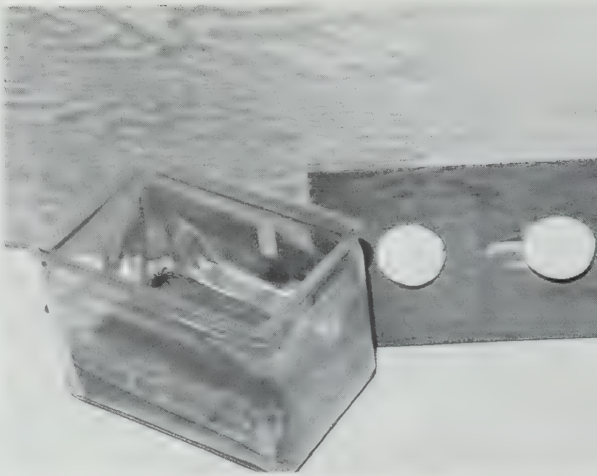


Figure B • 16 (*above, left*). Orb-weaver cage. Note that both the front and rear sides are hinged. This allows for opening the cage on the side opposite the web. Nylon screening is used on both sides. Once orb weavers establish a web, they do not try to escape and you can observe, feed, and photograph them without disturbing them.

Figure B • 17 (*above, right*). Glass aquarium with sandy soil covering the bottom. Note wooden top with cotton-plugged openings.

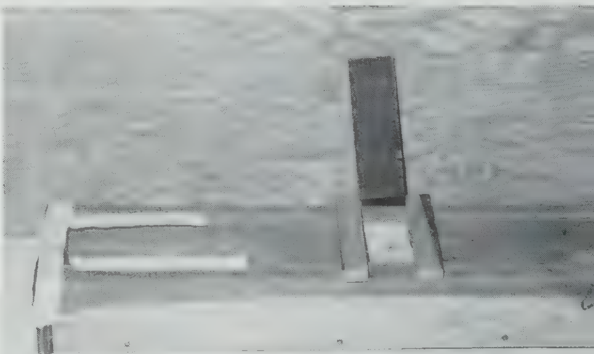


Figure B • 18 (*right*). Funnel web-weaver cage. Note the simple hinged opening for feeding.

You may wish to build a cage like one of those illustrated, or you may wish to use your own ingenuity and imagination to design and build other kinds of spider cages.

Regardless of what kind of jar or cage you use to keep spiders in, remember that they must be fed *live* insects every few days. Food may include flies, moths, mealworms, and so forth. Although spiders can survive without food for a week or more, they *must have* moisture. It is advisable to add a drop or two of water to the cage or jar every other day.

You may wish to keep spiders at home as well as at school. One advantage in keeping spiders at home is that you or a member of your family can observe their behavior during the evening

as well as during the daytime.

Once you have finished your observations of spiders in captivity, you should release them into the area in which you collected them.

Appendix C

Conversion Tables: Units of Measurement

LENGTH

English to Metric		*Metric to English*	
1 mile	= 1.6093 kilometers	1 kilometer	= 0.6214 mile
1 yard	= 0.9144 meter	1 meter	= 1.0936 yards
1 foot	= 0.3048 meter	1 centimeter	= 0.3937 inch
1 inch	= 2.5400 centimeters	1 millimeter	= 0.03937 inch

Metric to Metric

1 kilometer	= 1000 meters
1 meter	= 100 centimeters
1 centimeter	= 10 millimeters
1 meter	= 1 million microns
1 meter	= 1000 millimeters
1 micron	= 1000 millimicrons

VOLUME

English to Metric		*Metric to English*	
1 gallon	= 3.7854 liters	1 liter	= 1.0567 quarts
1 quart	= 0.9464 liter	1 milliliter	= 0.0338 ounce (fluid)
1 pint	= 0.4732 liter		
1 ounce (fluid)	= 29.6 milliliters	1 cubic centimeter	= 0.0338 ounce (fluid)
1 cubic inch	= 16.3871 milliliters		

Equivalents

1 liter	= 1000 milliliters
1 milliliter	= 0.061024 cubic inches

MASS (AND WEIGHT)

English to Metric

1 pound = 0.4536 kilogram
1 pound = 453.5924 grams
1 ounce (avdp) = 28.3495 grams

Metric to English

1 kilogram = 2.2046 pounds
1 gram = 0.0022 pound
1 gram = 0.03527 ounce (avdp)
1 milligram = 0.000035 ounce (avdp)

Metric to Metric

1 kilogram = 1000 grams
1 gram = 1000 milligrams

ABBREVIATIONS USED FOR UNITS OF MEASUREMENT

Word	*Abbreviation*	*Word*	*Abbreviation*
avoirdupois	avdp	liter	l
centimeter	cm	meter	m
cubic centimeter	cc	micron	μ (pronounced *mū*)
cubic inch	cu in	mile	mi
degree Centigrade	C	milligram	mg
degree Fahrenheit	F	milliliter	ml
fluid	fl	millimeter	mm
foot	ft	millimicron	mμ
gallon	gal	ounce	oz
gram	g	pint	pt
inch	in	pound	lb
kilogram	kg	quart	qt
kilometer	km	yard	yd

Prefix in Metric System	*Meaning*
mega-	1,000,000
kilo-	1,000
centi-	.01
milli-	.001
micro-	.000001

TEMPERATURE

Centigrade to Fahrenheit		*Fahrenheit to Centigrade*	
−273.18	−459.72	−400	−240
−250	−418	−300	−184.5
−200	−328	−200	−129
−150	−238	−100	− 73.3
−100	−148	− 40	− 40
− 50	− 58	0	− 17.3
0	32	20	− 6.7
10	50	32	0
20	68	50	10
30	86	70	21.1
50	122	100	37.8
100	212	150	65.6
150	302	200	93.3
200	392	500	260
500	932	1000	537.8
1000	1832	2000	1093.3
2000	3632		
3000	5432		

CONVERSION FORMULAS

$C = 5/9(F - 32)$
$F = 9/5C + 32$

Appendix D

Making and Maintaining a Terrarium

A terrarium is a glass case in which plants are grown. Usually these are ferns, mosses, bog plants, or other plants that need high humidity. But desert plants can do well if the humidity is kept low. Frogs, toads, salamanders, snakes, turtles, and the like, can be combined with the plants to produce a small community.

Terraria can be purchased, but they are expensive. A person with a knack for construction can easily build very good ones.

MATERIALS

Pieces of glass (Broken window glass or inexpensive glass can be purchased at a glass-repair shop.)

Glass cutter

Tape (Plastic tape comes in various colors.)

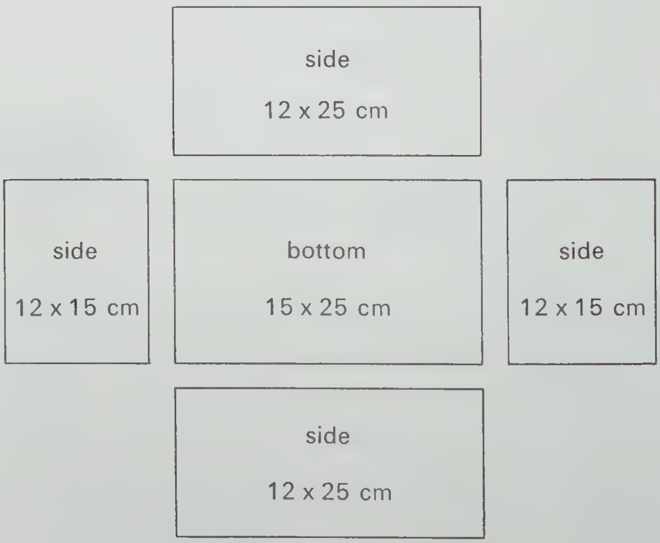
PROCEDURES

A. If the glass to be used cannot be obtained in the dimensions needed, cut it. Use a straight edge to guide the glass cutter and keep the edges square. A T square is best for this purpose. Draw the glass cutter firmly along the straight edge where the glass is to be cut. Dip the glass cutter in a light oil to make it move easily. The cutter etches a groove in the glass, and it is along this groove that the glass should break.

B. Put the glass on the edge of a table, with the etched side up. Press lightly on the overhanging glass; it should break off easily. Avoid etching the same line along the glass more than once. This will dull the glass cutter.

Six pieces of glass are needed for a terrarium. The following sketch gives the dimensions for small terraria, several of which could be set up in a classroom.

Figure D • 1.



The sixth piece of glass is for the top. It should be slightly larger than the bottom piece, so it can rest on the top of the terrarium without falling.

C. Tape the five pieces of glass together. Make sure the tape is on the outside. Run it along all the edges, and reinforce the corners with it. Tape all exposed edges so a person cannot be cut. Aquarium cement can help to hold the glass together, but do not expect the container to hold water.

When the terrarium is ready, a wide variety of organisms can be displayed and studied.

1. *Mosses and ferns* can be raised as follows: First, put a shallow layer of coarse gravel in the terrarium. Then add a 1.3-cm layer of sand and, finally, 2.5 cm of good, rich loam or loam and peat-moss mixture. Place the plants in the top layer and add water. Do not saturate the soil, as this will allow mold to grow. Keep the terrarium in medium light, with the top on. If humidity gets high, leave the top off for a little while.
2. *Bog plants,* such as Venus's-flytrap, pitcher plant, and sundew, will do well with about the same treatment as that given ferns and mosses. The addition of greater amounts of peat moss might help their growth. Capture small insects and place them in the terrarium so the action of insect-capturing plants can be studied. You may encounter problems in collecting bog plants; you can purchase them from biological-supply houses that specialize in live plant and animal materials.
3. *Cacti* can be grown in a desertlike environment. On the bottom of the terrarium, place coarse gravel covered by a layer of sand. Keep the cacti in small pots so they can be watered. Use the soil the cacti are collected from, or just keep them in the pot they were in when purchased. Bury the pots in the sand and keep the plants well lighted.
4. Put frogs, salamanders, toads, or small water snakes in either the bog or the fern terrarium. You can make a small "pond" by burying a shallow dish or pan and filling it with water. Feed the animals mealworms, small insects, earthworms, or salmon eggs.

5. Keep lizards in either the fern-and-moss or the desert terrarium. Lizards need water, so spray the leaves in the terrarium with water or put a small, water-filled jar lid in the sand for a supply. Feed lizards live food (such as mealworms or flies). They should have access to a small pond but be able to climb out on the land from time to time. If you are keeping turtles, place bits of fish, hamburger, liver, or earthworms in the pond because most turtles feed in water. See that the water is changed frequently.

Appendix E

Making a Plant Collection

All the animals in an area rely on plants for food, either directly or indirectly. To appreciate how living things interact with each other and their surroundings, we must study both plants and animals.

Collecting

The beginning collector needs very little equipment. Plastic bags, pencil and paper, a knife or some other cutting device, and some rubber bands are enough. Plastic lunch bags are sold by the box at any market.

As specimens are collected, they should be placed in the plastic bags, which are then closed with rubber bands. A large plastic bag will hold many plants, but sometimes the plants become tangled. If small bags are used, the collector should have a large container, such as a knapsack, to put them in. Moist paper towels can be put in the plastic bags to keep specimens fresh. If there is a delay between collecting and preparation, the unopened bags can be kept in a refrigerator.

For each plant gathered, note the habitat, locality, date, and other important information. Write this on a small piece of paper and put it in the plastic bag that contains the plant.

Do not dig up a whole plant, no matter how small. Instead, clip off a representative leaf, including its stem, and if possible a flower.

Before doing any collecting, check with an authority to learn what plants can or cannot be collected. Many plants are protected by law and should not be picked. And in some areas, such as state and national parks, *no* collecting is allowed.

Preparation and Display

All plants that will be used for display and study can be dried and pressed before being mounted on paper. You can buy plant presses that will both press and dry plants. Or an inexpensive press can be made from plywood, corrugated cardboard, newspaper, and small rope or heavy weights.

Cut two 30- x 45-cm rectangles of plywood, and several pieces of cardboard of the same size. Spread the plants on folded sheets of newspaper—one plant per sheet. Build a series of layers—plywood on the bottom, then a piece of cardboard, then a sheet of newspaper containing a plant—then start over again with another piece of cardboard, and so on. Continue in this manner, using about 12 plants. Using too many will delay drying and pressing. Top the "sandwich" with a final sheet of cardboard and a second piece of plywood. Tie the bundle securely with the rope to put very firm pressure on the plants. See Figure E • 1. Another method is to place several bricks or other weights on the plywood. This is often more convenient than tying.

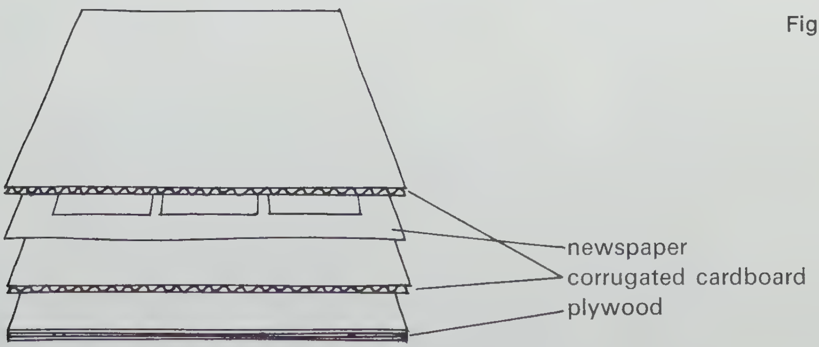


Figure E • 1.

Place the press in a cool, dry place. Check every two or three days to see if the plants are dry. When they are, they are ready for mounting. They should not be too dry, or they may become brittle and break.

Mounting the Plants

There are several ways to prepare dried plants for display. The following method is probably best for beginners. It is easy, and the product will last a long time.

MATERIALS

5 x 8 file cards (or larger if you prefer)

Scotch tape or clear seal plastic (Clear seal plastic can be purchased at a stationery store by the roll. Clear seal plastic is a contact material that will give an extremely good cover for the plant specimen.)

PROCEDURES

A. Place each plant on a file card and cover with tape or plastic. Many people find that drying and pressing are not needed if small cards are used. This is especially true in the drier parts of the country.

B. Each file card should contain this information:

Family—
Common Name—
Scientific Name—
Habitat—
Locality—
Date—
Notes—

Habitat refers to the type of surroundings where the plant was growing and could be described by such words or phrases as "grassy field," "meadow," or "oak woods." *Locality* refers to the area where the plant was collected, such as "New York City alley" or "swamp 5 miles south of Madison, Wisconsin." The notes can include special information—people's uses for the plant, historical notes, the plant's size, color or odor of the flowers, or any other worthwhile information.

Appendix F

Growing Plants and Animals for the Laboratory

One-celled animals (protozoa) show a tremendous variety of appearance and behavior. They live almost everywhere and so are easy to collect for temporary studies. Ponds, ditches, puddles, and streams are just a few of the locations where these small organisms may be found. Protozoa can also be purchased from biological-supply companies.

Most protozoa do well kept in small, shallow dishes containing water at a temperature of about 22°C. Keep the dishes loosely covered to maintain the water level. All dishes must be as clean as possible and all traces of soap or other chemicals removed. If you need to add more water to them, use sterilized water from a spring, aquarium, or pond. Tap water may be used if it is chlorine free. To sterilize water, boil it for about ten minutes.

It is possible, although difficult, to separate organisms collected from a pond or stream. Relatively pure cultures may be purchased from a biological-supply company.

Chilomonas:

These protozoa can be cultured fairly easily and used to feed a variety of other protozoa. Put four to six wheat grains into 100 ml of boiled water. Inoculate with a *Chilomonas* culture.

To make larger amounts of culture water, add 10 g of hay or dry grass to 1000 ml of distilled or spring water. Boil ten minutes, cool, and add *Chilomonas*.

Ameba:

Put about 200 ml of boiled water in a bowl and add four or five grains of polished rice. The quick-cooking rice sold in markets works well. Put in 2 ml of *Chilomonas* culture and 40 or 50 amebas.

Add water when needed to maintain the water level. As *Ameba* cultures become large, subculture by using more dishes and the same procedure as above.

Euglena:

These organisms sometimes are classified as protozoa and

sometimes as algae, for they can make their own food. Many interesting investigations can be done with *Euglena*, because they will respond to light. But how do they respond? What color of light will they respond to? Can they live without light?

Boil about 40 split peas in 1000 ml of water. Cool and place the culture solution in a gallon or half-gallon jar. Put in *Euglena*, cover the jar, and place it where direct sunlight is available. Subculture when the water becomes very green. Add a few more boiled peas each month and put in additional water when needed.

Paramecium:

This is probably the most common protozoan used in the classroom. Paramecia are large, respond to a variety of conditions, and are easy to culture. The culture solution must contain enough bacteria to support the paramecia. Bacteria are the main source of food for *Paramecium.*

Place a small handful of hay or dry grass in 1000 ml of tap water and boil for 20 minutes. Cool and let stand for 24 hours, then inoculate with *Paramecium*. The 1000 ml of culture solution can be divided among small bowls for ease of handling. Add small amounts of boiled hay each month, subculture when needed, keep in medium light, and maintain the water level.

Frogs

Frogs can be kept healthy if the proper conditions are met. The frogs must be fed and kept in clean, aerated water at about room temperature.

An aquarium used for frogs is tipped so that water covers about three-fourths of the bottom surface and is 10 to 12 cm deep at the lower end. Cover the tipped-up end of the aquarium bottom with paper toweling that extends into the water. This will keep that area moist. Change the water every two days and keep the water well aerated. Cover the container with wire screen that is fine enough to prevent the frogs from jumping out. To help prevent disease, add 1½ g of salt to every 1000 ml of tap water used.

To feed the frogs, mix together 100 g of hamburger, 0.5 g of fine-bone meal, and a few drops of cod-liver oil or some other source of vitamin D. Keep the mixture in a refrigerator between

feedings. Shape the food into small cylinders 2 cm long and no more than 0.5 cm in diameter. Hold a frog in one hand, force open its mouth, and use blunt forceps to push the food far back into the throat. Hold the mouth closed for a few seconds until the frog swallows the food. Feed the animals twice a week.

Plants

Yeast:

Add 10 ml of molasses to 180 ml of water. Put in ¼ package of dried commercial yeast (buy at any market). Keep the mixture in jars or flasks that are plugged with cotton. Put the containers in a warm, dark place for 24 hours.

Bacteria:

Bacteria live under such a great variety of conditions that it is impossible to describe all culture methods. These suggestions will allow you to prepare wet mounts showing a variety of bacteria.

Use sauerkraut juice or yogurt as a source of harmless bacteria. If you use yogurt, mix in a little water to obtain a liquid that can be used on a wet mount. Vegetables are another source of bacteria. Soak some beans or peas in water several days. Make a wet mount from the whitish scum at the top of the liquid. Almost any hay or dry-grass infusion will yield bacteria, especially if the samples are taken near the surface.

Molds:

Put some moist bread or fruit in a covered dish. Scatter or rub some dust on the food; then keep the dish in a dark, warm place for several days. Mold colonies will appear. The longer the bread or fruit is left, the greater will be the variety of molds found.

Put a few dead insects, such as flies, in a jar of pond water. Within a day or two, a whitish mass of mold will appear on the bodies. Leave a small jar of molasses, Karo syrup, or fruit juice exposed to the air in a warm, dark place for a few days. Molds of different types will usually appear on the surface. Try different combinations of insects and liquids to find the best combination for growth of molds.

Elodea:

Many investigations call for the use of *Anacharis* ("elodea"

is the common name). Most tropical-fish stores or pet shops carry elodea, but it may be expensive or difficult to obtain. An aquarium can be set up just for the growth of elodea. Such a source will always be in the classroom and can be used any time.

The special aquarium for elodea should be better lighted than the average aquarium. Keep its temperature at about 22°C to ensure the best conditions for growth. Make sure the water used in the aquarium is conditioned by allowing it to stand for a day or two before adding elodea.

Geraniums and coleus:

Geranium and coleus plants may not always be available for purchase when needed, or they may be too expensive to buy in large numbers. A few healthy plants can be used for cuttings. These cuttings can be rooted and later transplanted. If geraniums or coleus are going to be propagated by cuttings, the work should be carried out well in advance of the use of the plants in the laboratory. It takes time to grow plants large enough for laboratory work.

Select a young, vigorously growing geranium or coleus plant for cuttings. Cut squarely across the stem or a good, vigorous branch, about 8 cm below the tip, with a sharp knife or razor blade. Remove most of the leaves, but allow a few young ones near the tip to remain.

Plant the cutting about 2 cm deep in moist sand or sphagnum moss. Make sure the planting medium is well drained to prevent rot. Keep moist by covering the cuttings with newspaper or plastic for two or three days. Do not expose the plants to strong sunlight.

After two or three weeks the cuttings will have grown roots and will be ready for potting. Use small pots that have been thoroughly soaked with water. You can make potting mix by mixing together 3 parts loam, 1 part sand, and 1 part humus. Many nurseries sell bagged potting medium. Make sure the soil is moist before putting it into the pots. In each pot place a small rock or piece of broken pot over the drainage hole to prevent rapid loss of moisture during watering.

Use a broad knife or spatula to transfer each cutting to a pot. Remove the cutting carefully along with the sand surrounding the

root. With your fingers, scoop a hole in the soil. Put the cutting in the hole and pack the soil loosely with your hand. After growth has started, the plants can be transferred to larger pots.

Appendix G

Scientific Terms

As you take more classes in science, you will discover that scientists not only use scientific names for different animals and plants but also have specialized terms to describe many of the other things they talk and write about. Indeed, it has been said that a student in a biology course may learn as many new words as a student in a French or German course.

It is very important in science, of course, to be specific. Thus, in biology every structure must have its own name; there are specific terms even for directions such as "at the front end" and "back." Like scientific names of organisms, scientific names of structures are Latinized and are often compound—that is, made up of several parts. The terms frequently appear complicated and may seem to make no sense, and it often takes some doing to pronounce them. But they may be very meaningful. And it can prove fun figuring out what the words mean rather than being frightened by them simply because they look so strange.

Unfortunately, throughout the history of science there has been a tendency for people in new areas of science to develop entirely new sets of terms. So many new terms, indeed, that those for just one field may fill an entire dictionary. As a field like this matures, some of the extra terms are discarded—this is going on in biology today—but the individual sciences will always be characterized by possessing their own languages. Probably one reason some people don't care for the sciences is that they seem to be in large part like foreign languages. But you can appreciate why they need special words—and you may grow up without that dislike for science which has in the past separated science and the scientist from the so-called man in the street.

As was true with scientific names of organisms, you can often discover the meaning of a scientific term by looking up the parts of the term in a good dictionary. The biological terms that follow will give you an introductory acquaintance with specialized words and perhaps stimulate you to find out about other scientific terms that you run across in your reading (they are often used, even in newspapers). The 18 terms here look pretty imposing, but most of them are in fairly common use. To make your work easier, the words have been separated into their parts. Using the glossary that follows, try to figure out what each of the biological terms means. Then try to match each of these terms with the appropriate definition on page 361 or 362.

I. BIOLOGICAL TERMS

1. Adrenocorticotropic hormone (*adreno-*, *cortico-*, *-tropic*)
2. Amylase (*amyl-*, *-ase*)
3. Antihistamine (*anti-*, *-histamine*)
4. Arteriosclerosis (*arterio-*, *-sclerosis*)
5. Autotrophic (*auto-*, *-trophic*)
6. Biceps (*bi-*, *-ceps*)
7. Biology (*bio-*, *-logy*)
8. Carnivore (*carni-*, *-vore*)
9. Ecology (*eco-*, *-logy*)
10. Electrocardiograph (*electro-*, *cardio-*, *-graph*)
11. Epidermis (*epi-*, *-dermis*)
12. Erythrocyte (*erythro-*, *-cyte*)
13. Hemoglobin (*hemo-*, *-globin*)
14. Hyperacidity (*hyper-*, *-acidity*)
15. Pandemic (*pan-*, *-demic*)
16. Phagocyte (*phago-*, *-cyte*)
17. Polymorphonuclear leucocyte (*poly-*, *morpho-*, *-nuclear*, *leuco-*, *-cyte*)
18. Vitamin (*vit-*, *-amin*)

II. GLOSSARY

acidity = amount of acid
adreno = adrenal gland
amin = protein
amyl = starch
anti = against
arterio = arterial

ase = enzyme
auto = self
bi = two
bio = life
cardio = heart
carni = meat
ceps = heads
cortico = outside portion
cyte = cell
demic = people
dermis = skin
eco = home, dwelling place
electro = electric
epi = outer
erythro = red
globin = blood-cell protein
graph = instrument for making records
hemo = iron
histamine = substance causing allergy
hormone = compound which "stirs up"
hyper = excessive, super
leuco = white
logy = study of
morpho = shape
nuclear = nucleus
pan = all
phago = eating, devouring
poly = many
sclerosis = hardening
trophic = nourishing
tropic = changing
vit = life
vore = eating

III: DEFINITIONS

a. Study of the relationship between organisms and their environment.
b. Organisms that produce their own food (for example, photosynthetic plants).
c. An enzyme that breaks down starch.
d. The outer portion of the skin.
e. A white blood cell that has a many-shaped nucleus.
f. A large muscle in the upper arm that has two heads, or points of attachment to bone.
g. A compound, sometimes protein, that is essential for life processes.
h. Iron compound in red blood cells, composed of protein.
i. An excessive amount of acid.
j. Hardening of the arteries.
k. An organism that eats meat (usually used to refer to a meat-eating mammal).

l. An instrument that records electrical changes in heart muscle.
m. A compound that combats allergic reactions.
n. A disease affecting people all over the world.
o. A compound, produced by the pituitary gland, that controls the cortex (outer portion) of the adrenal glands.
p. A red blood cell.
q. A cell that devours other cells (or disease organisms).
r. The study of living things (or life).

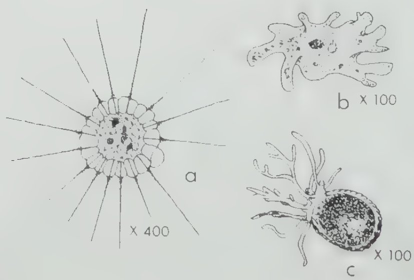
Appendix H

Guide to Some Common Freshwater Organisms

(Courtesy of Biological Sciences Curriculum Study, *BSCS Green Version, High School Biology.*)

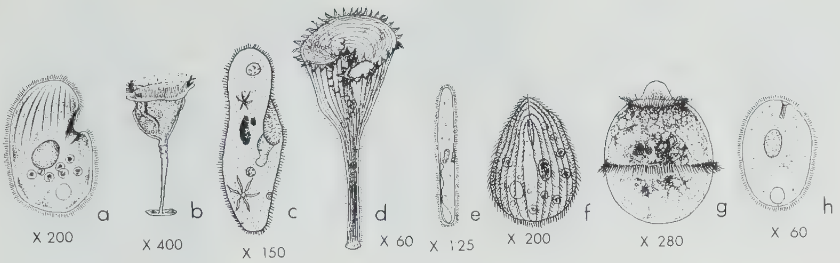
Microscopic Organisms

Amoeboids



AMOEBOIDS: Pseudopods present. (*a*) *Actinosphaerium* (spherical, with stiff, radiating projections); (*b*) *Amoeba* (pseudopods, no shell); (*c*) *Arcella* (shell present)

Ciliates

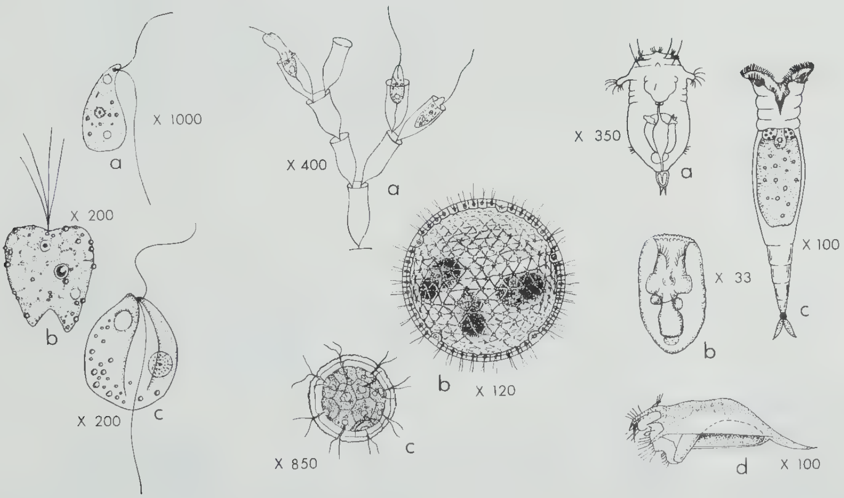


CILIATES: Cilia on all or part of body. No flagella. Some have chlorophyll. (*a*) *Colpoda;* (*b*) *Vorticella;* (*c*) *Paramecium;* (*d*) *Stentor;* (*e*) *Spirostomum;* (*f*) *Tetrahymena;* (*g*) *Didinium;* (*h*) *Prorodon*

Unicellular flagellates (*left*)

Colonial flagellates (*middle*)

Rotifers (*right*)



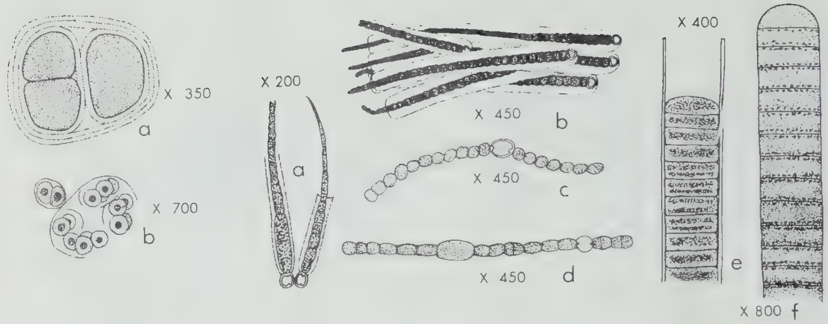
UNICELLULAR FLAGELLATES: One or more long, whiplike flagella. With or without cilia. Colorless. (*a*) *Spironomas;* (*b*) *Collodictyon;* (*c*) *Colponema*

COLONIAL FLAGELLATES: (*a*) *Codonodendron;* (*b*) *Volvox* (constantly rotating) ; (*c*) *Pandorina*

ROTIFERS: Bands of cilia near mouth. Colorless. (*a*) *Synchaeta;* (*b*) *Asplanchna;* (*c*) *Philodina;* (*d*) *Keratella*

Simple
blue-green algae
(*left*)

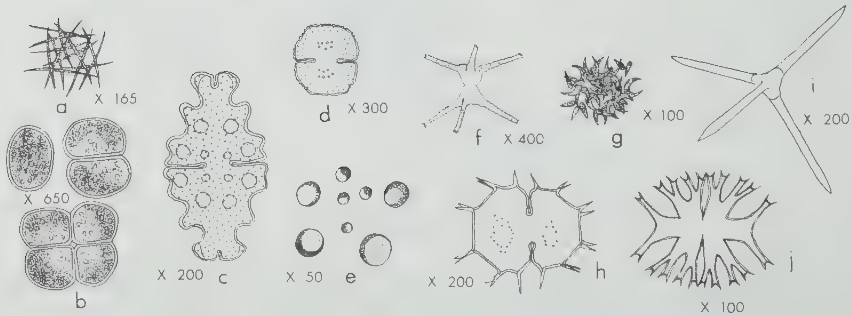
Filamentous
blue-green algae
(*right*)



SIMPLE BLUE-GREEN ALGAE: Dark green or blue-green clusters in gelatinous sheaths. (*a*) *Chroococcus;* (*b*) *Gloeocapsa*

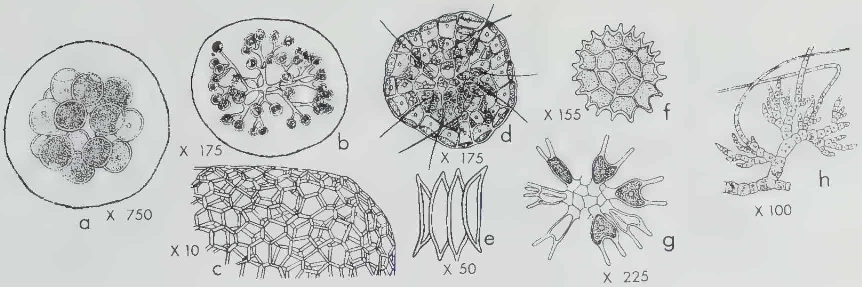
FILAMENTOUS BLUE-GREEN ALGAE: (*a*) *Gloeotrichia* (in gelatinous sheaths that often run together); (*b*) *Rivularia* (tapering filaments in sheaths); (*c*) *Nostoc* (firm sheaths); (*d*) *Anabaena* (cells of different sizes, in chains); (*e*) *Lyngbya* (thin sheaths); (*f*) *Oscillatoria* (no sheaths)

Single-celled
green algae



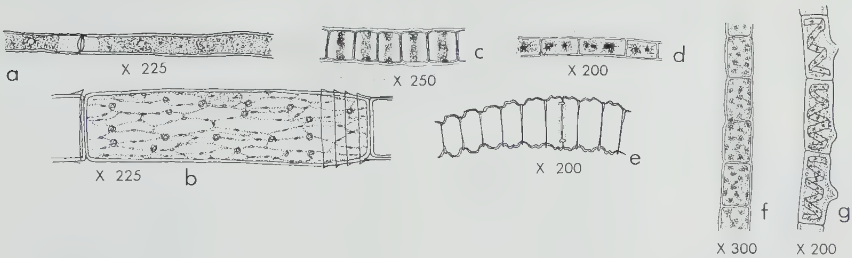
SINGLE-CELLED GREEN ALGAE: (*a*) *Ankistrodesmus;* (*b*) *Protococcus;* (*c*) *Euastrum;* (*d*) *Cosmarium;* (*e*) *Chlorella;* (*f*) *Staurastrum;* (*g*) *Selenastrum;* (*h*) *Xanthidium;* (*i*) *Treubaria;* (*j*) *Micrasterias*

Colonial green algae



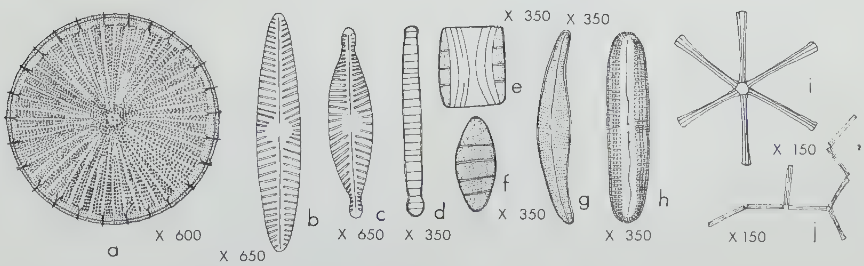
COLONIAL GREEN ALGAE: (*a*) *Sphaerocystis;* (*b*) *Dictyocphaerium;* (*c*) *Hydrodictyon;* (*d*) *Coleochaete;* (*e*) *Scenedesmus;* *(f) Pediastrum;* (*g*) *Sorastrum;* (*h*) *Chaetophora*

Filamentous green algae



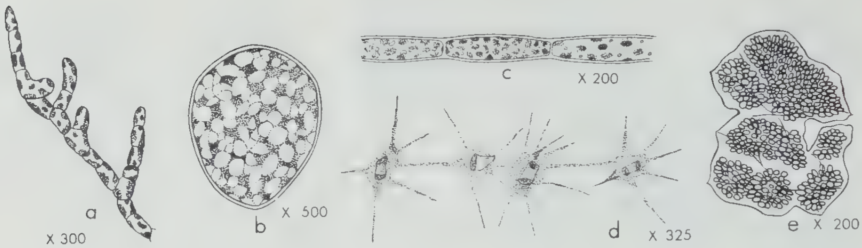
FILAMENTOUS GREEN ALGAE: (*a*) *Mougeotia;* (*b*) *Oedogonium;* (*c*) *Ulothrix;* (*d*) *Zygnemopsis;* (*e*) *Desmidium;* (*f*) *Microspora;* (*g*) *Spirogyra*

Golden algae (diatoms)



GOLDEN ALGAE (DIATOMS): Unicellular or loosely colonial algae. Walls of silica, consisting of two overlapping halves that fit together like the halves of a petri dish. (*a*) *Stephanodiscus;* (*b*) *Navicula gracilis;* (*c*) *Navicula rhynocephala;* (*d*) *Diatoma elongatum;* (*e*) *Diatoma hiemale* (girdle view); (*f*) *Diatoma hiemale* (valve view); (*g*) *Cymbella;* (*h*) *Pinnularia;* (*i*) *Asterionella;* (*j*) *Tabellaria*

Other golden algae



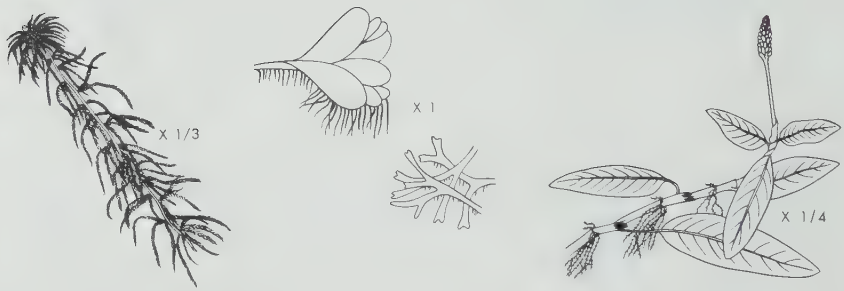
OTHER GOLDEN ALGAE: (*a*) *Monocilia* (branching filaments); (*b*) *Leuvenia* (ovoid or pear-shaped, solitary); (*c*) *Tribone* (cells cylindrical, joined end-to-end); (*d*) *Chrysidiastrum* (amoeboid cells joined in free-floating colonies); (*e*) *Botrycoccus* (compact, irregular, gelatinous, semiopaque masses)

Macroscopic Plants

Moss (*left*)

Liverworts (*middle*)

Smartweed (*right*)



MOSSES: Submerged or emergent. Erect, feathery stalks.

LIVERWORTS: Flat and ribbonlike. Rootlike structures on undersurface. Above: *Ricciocarpus;* below: *Riccia*

SMARTWEEDS: Emergent. Small flowers in dense clusters.

Sedge (*left*)

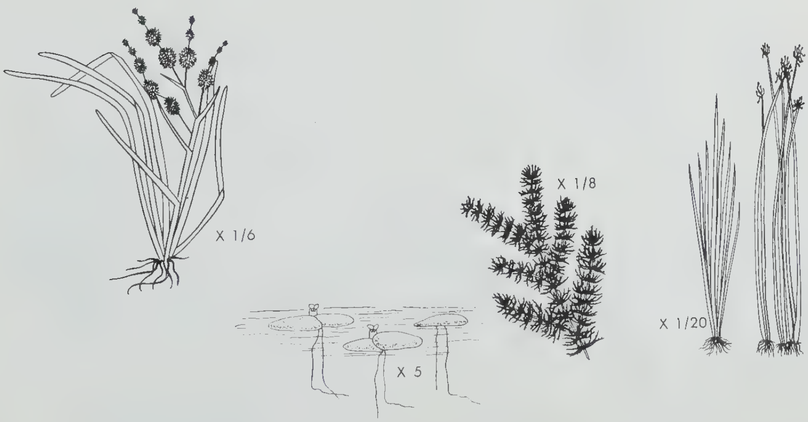
Arrowhead (*middle*)

Chara (*right*)

SEDGES: Emergent. Stems triangular in cross section.

ARROWHEAD: Emergent. Leaves shaped like broad spearheads.

CHARA: Submerged. An alga with whorled branches.



Bur reed (*left*)

Duckweed (*middle left*)

Coontail (*middle right*)

Rushes (*right*)

BUR REED: Emergent. Long, grasslike leaves may be submerged.

DUCKWEED: Floating. Roots hang in water. Frequently forms extensive mats.

COONTAIL: Submerged. Leaves stiff, hairlike, branched in whorls. No roots.

RUSHES: Emergent. Leaves grasslike. Clusters of small fruiting structures.

Cattails (*left*)

Tape grass (*middle left*)

Mare's tail (*middle right*)

Pickerelweed (*right*)

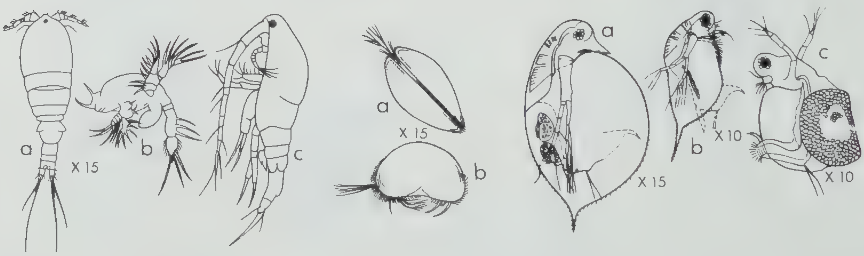
CATTAILS: Emergent. Tall, grasslike leaves. Long, brown fruiting structures.

TAPE GRASS: Submerged. Leaves ribbonlike. Plant rooted to bottom. Flowers break off and float to surface.

MARE'S TAILS: Submerged. Leaves small, simple, in whorls.

PICKERELWEED: Emergent. Leaves heart-shaped. Flowers (purple) tightly clustered on slender spike.

Arthropods



Copepods (*left*)

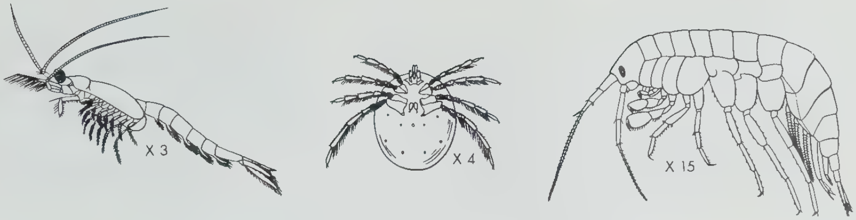
Ostracods (*middle*)

Cladocerans (*right*)

COPEPODS: Small crustaceans with several hairlike spines at tip of abdomen. Body elongated. (*a*) *Halicyclops;* (*b*) *Diaptomus* (a larval stage); (*c*) *Diaptomus* (adult)

OSTRACODS: Small crustaceans with no spines. Body covered by a jointed carapace, somewhat resembling small clamshells.

CLADOCERANS: Small crustaceans with no spines at tip of abdomen, or a single spine only. Body short. (*a*) *Daphnia* (female); (*b*) *Daphnia* (male); (*c*) *Ceriodaphnia*

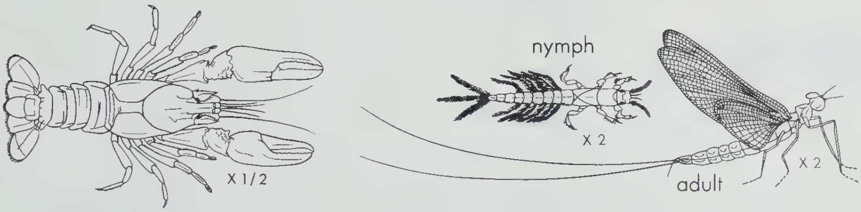


Opossum shrimp (*left*)
Water mite (*middle*)
Scud (*right*)

OPOSSUM SHRIMPS: Carapace covers most of thorax. All limbs of thorax similar. Eyes stalked. No gills in most species.

WATER MITES: Body not jointed. Eight jointed legs.

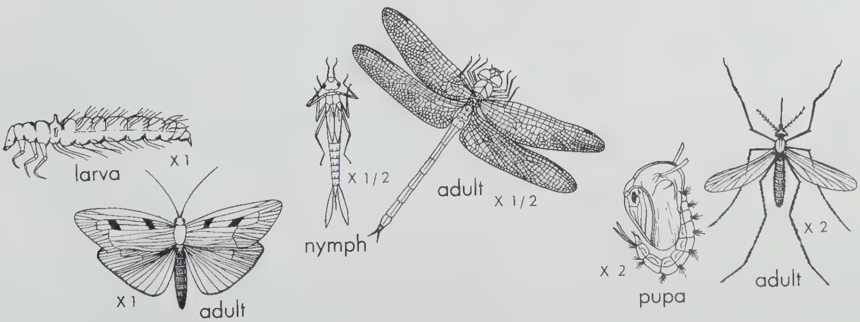
SCUDS: No carapace. Limbs of thorax different from each other. Eyes not stalked. Body compressed laterally. Gills present.



Crayfish (*left*)
Mayfly (*right*)

CRAYFISH: Carapace not jointed. Pincers on anterior legs.

MAYFLIES: Adults usually have clear, narrow wings. Wings usually held vertically when at rest. Larvae aquatic. Adults and larvae with three "hairs" at end of abdomen.



Caddis fly (*left*)
Dragonfly (*middle*)
Mosquito (*right*)

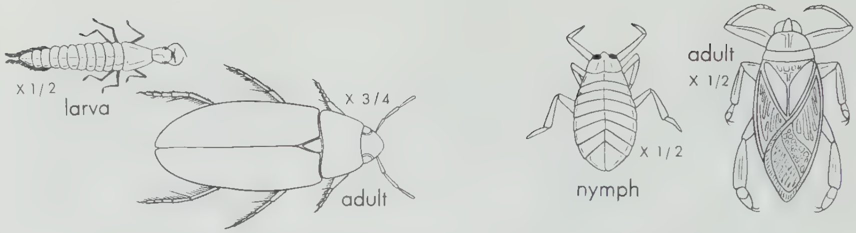
CADDIS FLIES: Adults have clear, broad wings. Larvae aquatic, wingless, and usually live within cases composed of pebbles or debris.

DRAGONFLIES: Adults large, usually clear-winged. Wings extend horizontally when at rest. Large eyes. Larvae aquatic. End of abdomen without "hairs."

MOSQUITOES: Adult has only one pair of wings. Larvae small, without legs, float at surface of water, and breathe air through tubes.

Water scavenger (*left*)

Giant water bug (*right*)



BEETLES: Adult has a pair of hard wing covers, not overlapping. Larvae wingless. Example: water scavenger.

BUGS: Adult has a pair of overlapping wings. No hard wing covers. Larvae wingless. Example: giant water bug.

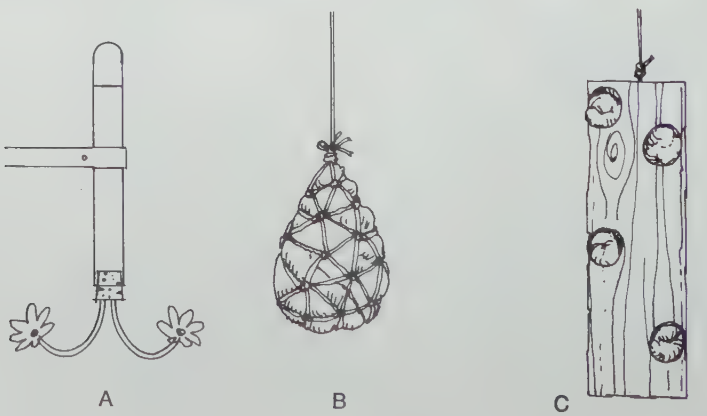
Appendix I

Studying Wild Birds

Watching wild birds provides an excellent way for you to observe how animals are adapted to their habitats. In almost any area, some kinds of birds can be attracted to a feeding station. Once there, they will probably stay long enough for you to take notes on their appearance and behavior and perhaps photograph them.

A feeding station should include at least one seed shelf, several suet (hard beef-kidney fat) baskets or logs, and a hummingbird feeder (Figure I • 1). The best feeding shelves have overhanging roofs, to keep food dry, and are made of rough wood. Avoid using

Figure I • 1.



metal, smooth surfaces, and bright colors for them. If possible, place a birdbath near a feeding station. Most birds are attracted by dripping water or water bubbling from a small fountain (Figure I • 2). The depth of water in the bath should be between 2 and 5 cm—not more. Again, avoid smooth, slippery containers.

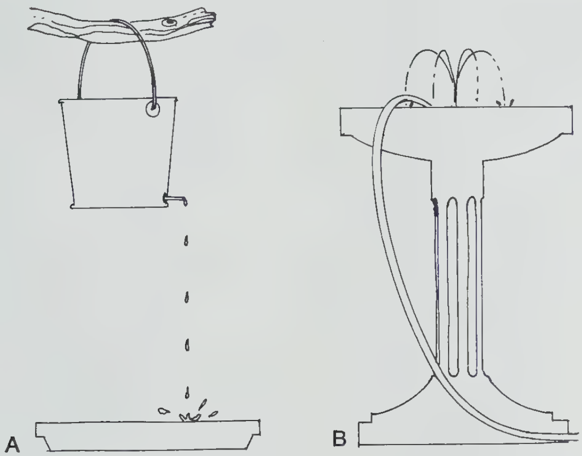


Figure I • 2.

When you attract birds, you may also attract cats; place feeders and baths in an open spot or at least 5 meters from any place where cats might hide.

A variety of foods should be offered in a feeding station so that differences in food choice and feeding habits can be observed. Ideally, the foods should include large and small seeds, nuts, and raisins and other fruits. Chick scratch alone will attract many birds. Also, chick scratch may be cooked with cornmeal, nuts, suet, and raisins and cooled to form a "cake" that many birds will eat.

Observe how the birds use their feet, legs, tails, and wings in approaching food. A bird may creep along the limbs or trunk of a tree, head up or head down, propping with the tail or not. It may make a direct or an indirect flight to the food, using the wings and tail for braking or maneuvering in the air. Or it may hover near the food. You may be able to see a relationship between the kind of beak a bird has and its choice and handling of food.

To summarize your observations, take notes in a "bird log." An example of an entry is shown on page 372. Notes on each bird entered should include its common name or a description; its exact

location; its use of feet and legs, wings and tail, and beak; its response to other intruders, such as cats or people; its choice of food; the time of day it was seen.

BIRD LOG

Location: Smith Junior High School, Brownsville, Iowa. Feeding station on north side of school, near maple tree on corner.

Date: April 10, 1975.

Time: 7:40 A.M.

Weather: Sky—Light clouds.
Temp.—20°C.
Wind—Light NW breeze.
Precipitation—None.

Observations: Bird about canary size, but heavier. Black streaked, cheeks and belly white, throat black. Flew about 5 meters from eaves of school to feeding tray, driving two other birds from it before eating grain.

Summary and Conclusion: House sparrow, male. Likes the grain. Does not want other birds on tray.

ANNOTATED REFERENCE LIST

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An * indicates an illustration.

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